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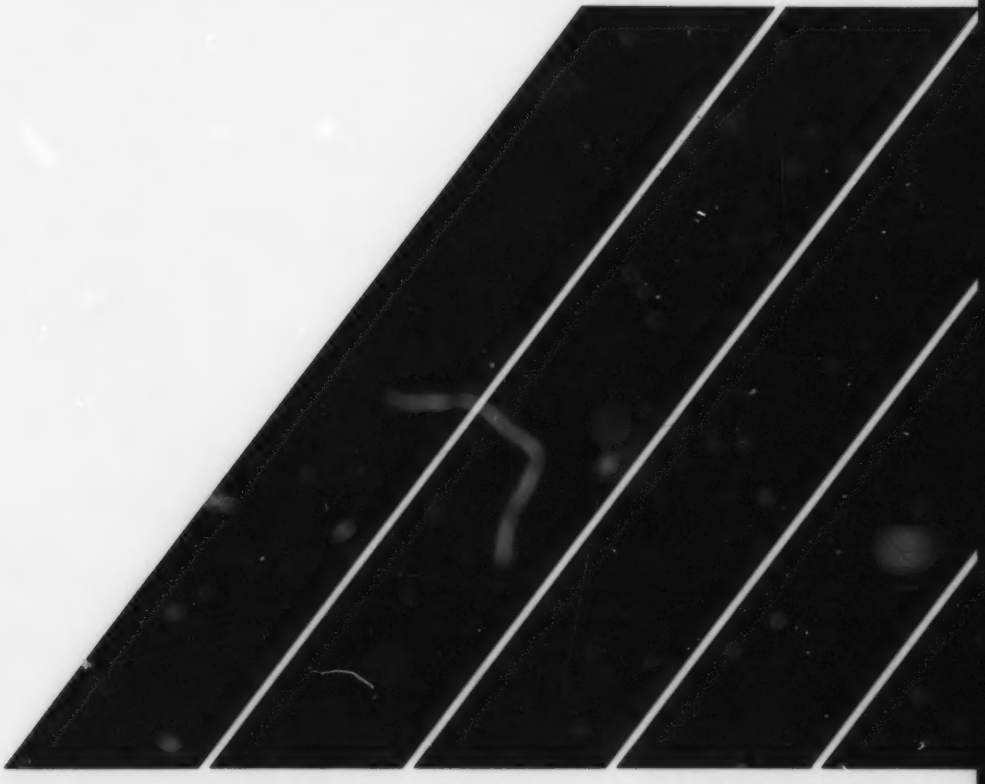

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VISROCK

An Elasto-ViscoPlastic Program for Rocks
User's Manual, version 1.0

Richard G. WAN
Guylaine Hamel

MRL 92-037(TR) April 1992

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54 pp

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MICROMEDIA

User Manual

for

VISROCK

An Elasto-ViscoPlastic Program for Rocks

Version 1.0

©

Richard Wan

and

Guylaine Hamel

April 1992

92-06297/

Executive Summary

This report provides documentation for VISROCK a finite element program for the elasto-viscoplastic analysis of plane strain and axisymmetric geostructures. The code is structured in such a way to be general enough to accommodate three dimensional structures and solve general solid mechanics problems. In this version of the program, only two-dimensional structures can be examined.

The finite element formulation used is based on the small deformation theory while elasto-viscoplasticity is treated as a standard initial strain problem. The program has a number of special capabilities: it can model a full range of plane and axisymmetric problems using 4-node or 8-node serendipity elements. The available material models include a simple isotropic linear elastic material model and an elasto-viscoplastic model with cohesion and friction hardening or softening. In order to allow the user to step progressively through the load/mining history of a particular problem, a restart feature has been implemented. The data file for VISROCK can be either constructed by following the input instructions described in this manual, or be automatically reproduced by means of a pre-processor program which generates the mesh geometry and merges information regarding material properties, mining step sequence, load definition and time integration parameters. The results at each beginning of a mining step as well as intermediate user specified times can be graphically visualized. These are explained in the post-processor manual.

Summary of Capabilities

The summary of the program capabilities outlined below is followed by a detailed user input description. Most of the options described below are general in implementation and should work in any combination unless otherwise stated.

Formulations:

- Small displacements as well as infinitesimal strains

Elements:

- Two dimensional isoparametric element (plane stress, plane strain or axisymmetric) linear or quadratic

Material Models:

- Isotropic linear elastic
- Elasto-viscoplastic with cohesion and friction hardening or softening

Solution Strategy:

- Implicit or explicit marching scheme for time integration
- Initial strain method for equilibrium search

Equation Solver:

The program uses the appropriate in-core skyline solver depending on whether the stiffness matrix is symmetric in shape and values, or non symmetric in values but symmetric in shape.

Loads:

All loads can be read for each load (mining) step or adjusted from the previous load step. The types of load supported include:

(a) Concentrated nodal loads
(b) Normal and tangential surface tractions
(c) Prescribed displacements
(d) Initial in-situ stresses

Special Capabilities:

- Birth and death for excavation and backfill activities
- Graphics

  Pre-processor

    mesh design

    mesh generation

    mesh editing

  Post-processor

    mesh

    deformed mesh

    principal stress orientations

    stress contours

    viscoplastic contours
- Restart

Running Capacity:

- VISROCK runs for meshes in excess of 2500 4-noded iso-parametric elements

Acknowledgements

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Contents

Executive Summary i

Summary of Capabilities ii

Acknowledgements iv

1.0 Introduction 1

1.1 Method 1
1.2 Formulation 1
1.3 Elements available 2
1.4 Material Models 2
1.5 Loading 2
1.6 Solution Strategy 2
1.7 Birth and Death of Elements 3
1.8 Restart 4

2.0 Program Structure 4

2.1 VISROCK Files 4
2.1.1 File Assignments 4
2.1.2 Input Files 7
2.1.3 Output Files 7
2.2 Memory Allocation 7
2.2.1 Global Memory Specification 7
2.2.2 Array Pointer and Handle Allocation 7

References 8

APPENDIX 9

0.0 HEADING CARD 10
1.0 PRINT INITIATION BLOCK 11
2.0 COMMENTS BLOCK 12
3.0 NODAL COORDINATES BLOCK 13
4.0 BOUNDARY CONDITIONS BLOCK 15
5.0 ELEMENT PROPERTIES BLOCK 16
6.0 ELEMENT CONNECTIVITY BLOCK 20
7.0 INITIAL STRESS BLOCK 22
8.0 LOAD BLOCK 24
9.0 VISP BLOCK 27

10.0 CLOSURE BLOCK.....31

EXAMPLE 32

Sample Problem for Excavation.....32
Sample Input 33
Sample Output (showing partial results at selected times) 34

1.0 Introduction

The program VISROCK is based on a heavily modified version of MEF3 a finite element code developed by Dhatt and Touzot (1984) of Laval University. This program has been chosen as basis because it is very modular and has three dimensional capabilities. Hence extension to 3-D stress and geometric conditions is straightforward. The elasto-viscoplastic algorithm, patterned after Owen and Hinton (1980), has been enhanced and extended to frictional materials. It is intended to be directly applicable to the analysis of time dependent behaviour of geomaterials such as potash. Although the program is not a general purpose finite element code, it is applicable to a full range of plane and axisymmetric problems. The following sections provide a description of the capabilities of the program. The appendix provides a detailed user's manual to describe the input format of the program.

1.1 Method

The implementation of elasto-viscoplasticity is patterned after the classical Perzyna-type model which is a straightforward extension of inviscid plasticity to the rate dependent case by postulating a flow rule based on a "plastic" potential and a fluidity parameter for time effects.

The concept involves the choice of an empirical failure criterion—herein mathematically represented by either von-Mises, Mohr-Coulomb, or Drucker-Prager functions—to define the onset of inelastic deformations. The material is assumed to be linear elastic prior to yielding. Once yielding occurs, time dependent plastic deformations are deemed to take place until a steady condition is reached at which the final stress regime returns to a state on the yield surface. The viscoplastic flow is a characteristic of the type of material under investigation. In this implementation, both a power law and exponential decay are considered. This is by no means a restriction imposed to the program because the formulation is general enough to permit an easy code modification to incorporate any arbitrary function (actually a regularization function for plastic dissipation).

1.2 Formulation

VISROCK is based on the incremental Principle of Virtual Work. It allows for a small displacement infinitesimal strain formulation for the mean time, but can be readily extended to large displacement formulations. The material behaviour is based on elastic viscoplastic

behaviour in which a body initially undergoes an instantaneous elastic response, followed by the development of time dependent irrecoverable strains in regions of the body where the stress level exceeds yield conditions. Owing to the nature of viscoplasticity, the analysis requires iterative or time integration algorithms for obtaining the boundary-valued problems. Both implicit and explicit time integration schemes are provided in the program

1.3 Elements available

The program provided allows for two dimensional isoparametric elements for plane stress, plane strain and axisymmetric formulations. The classical formulation is based on small deformation field. The element can have 4 or 8 nodes for linear or quadratic field discretization.

1.4 Material Models

The material models in the program are based on simple isotropic linear elasticity and elasto-viscoplasticity. Time dependent behaviour is controlled by a generic creep law function which can be either an exponential or a power law, while strength is governed by criteria such as Mohr-Coulomb, Drucker-Prager, Tresca and von-Mises. Viscoplastic flow is associated, i.e based on a viscoplastic potential which coincides with the yield function, but non-associative laws can be readily accommodated. Material degradation is modelled by a phenomenon of cohesion and friction softening. It is by this means that tertiary creep can be captured.

1.5 Loading

The program allows a variety of load types such as concentrated nodal loads, gravity loads, normal and tangential surface tractions, prescribed nodal displacements. An initial stress field can also be prescribed which is automatically interpreted and applied as work equivalent external nodal loads. At each mining step, both tractions and concentrated nodal loads can be applied incrementally to simulate respectively support pressures provided by casings and rock bolts reinforcement.

1.6 Solution Strategy

The elasto-viscoplastic equations are integrated using either a fully implicit, semi-implicit or fully explicit scheme. This is controlled by the parameter α which varies between 0(fully

explicit) and 1(fully implicit). It is normally known that for values of $\alpha > 1/2$ the scheme is numerically stable, but does not guarantee accuracy of the solution unless a proper time step length is used. The stiffness matrix has to be constructed at every time step and may result into a lot of computations.

For values of $\alpha < 1/2$ reformulation of the stiffness matrix is not necessary, but the integration scheme is conditionally numerically stable and is subjected to a critical time step length which can be derived in only special cases, see Cormeau (1975).

In a general boundary-value problem involving arbitrary material behaviour, a critical time step cannot be formally derived. As such, in VISROCK, the time step is controlled by empirical criteria based on maximum effective viscoplastic strain increment as a fraction of the total effective strain—basically a measure of viscoplasticity. This ratio is called TAUFT in the program. Usually the value of TAUFT is between 0.01 and 0.15, but higher values can be used in the implicit case, subject to some experimenting. In addition, the next time step is limited to 1.5 times the previous one. This is controlled by the parameter FTIME. Equal, rather than variable, time step intervals can still be achieved in the time marching scheme by assigning a high value to TAUFT and putting FTIME=1. The user is referred to the theoretical manual, section 3.7 in Wan (1992) for further details.

Mining activities can take place at any given time, even a steady state has not been reached. The analysis moves on to the next mining activity if a steady state is reached well before the next mining event.

The equations are solved using an in-core skyline solver. The stiffness matrix is symmetric in form but may or may not be symmetric in values. Therefore asymmetric solving is possible and is used only when a non-associated viscoplastic flow rule used.

1.7 Birth and Death of Elements

A full capability for killing and element or giving birth to it (deactivating and deactivating for excavation and backfill respectively).
Loading conditions encountered in mining activities such as excavation/backfilling are modelled within VISROCK by means of a consistent formulation for a time dependent shrinking or expanding body. This algorithm is at variance with other techniques which consist of applying fictitious forces along excavated boundaries, or more primitively, assigning very low material properties (that of air) to simulate excavated areas. The present excavation/fill algorithm is variationally consistent for a non-linear solution, and ensures

unique solutions for elastic situations with regards to sequencing, see Appendix B of theoretical manual.

The placement of fill can be done in two ways: either a non-prestressed or prestressed configuration. A backfill is normally stress free when put in place, but the effect of slippage at the interface host-fill cannot be modelled presently in the program. In the prestress option, the prestress is calculated based on displacement values needed for the backfill to conform with the original shape of the excavated boundary. This option is never used since most backfills are usually stress free.

1.8 Restart

The program provides a restart facility which allows rerun of the analysis at any point in the time domain. Note that the two last time step results are stored in a restart file called RESTART.DAT to ensure the proper recovery of pertinent information.

2.0 Program Structure

2.1 VISROCK Files

2.1.1 File Assignments

The block `VISP` uses seven different files for the purpose of input, output, post-processing and as well as for temporary storage. The following table lists the file names, the unit number to each file is assigned and a brief description of the file's purpose:

File Type	Assigned unit No./type	File contents and description
`FICHELM.DAT`	1/Direct access/ unformatted	A file which contains basic element information which includes element number, group, type, material type, global equation numbers, nodal coordinates, material properties, connectivities and external force.

M2 (scratch)	2/ sequential/ unformatted	A file which contains the global external force array.
M3 (scratch)	3/sequential/ unformatted	A file which contains the global stiffness matrix stored in skyline fashion. For an asymmetric stiffness matrix, the lower diagonal elements are stored in a new record.
RESTART. DAT	4/sequential/ unformatted	A file which contains the pertinent informations to permit a restart run. The last two time steps are always stored to ensure correct recording of information during a breakdown.

Time Step Info:.
rec 1. `NREC, ISTEP, TTIME, DTIME, ICHK, FIRST`

Change of Element Property Info:.
rec 2. `KPROP(I), I=1, NELT)`

Element Info:.
rec 3,.....,3+`NELT`: contents of `FICHELM.DAT`

Global Force Array:
next record: `(VFG(I), I=1, NEQ)`

Global Stiffness Matrix:
next record: `(VKGS(I), I=1, NKG), (VKGD(I), I=1, NEQ)`
or for axysymmetry:
next record:
`(VKGI(I), I=1, NKG)`

Global Current Displacement:

next record: `(VLDG(I),I=1,NEQ)`

Stresses and Strains/Rates:

next record: `(VSTRS(I),I=1,2*NDIM*NPG)`
next record: `(VSTRN(I),I=1,2*NDIM*NPG)`
next record: `(VRATE(I),I=1,(2*NDIM+1)*NPG)`

`DUMP.DAT` 5/sequential/unformatted

A post-processor file which contains all pertinent information (displacement, stresses and strains) at each user specified time frequency and at the beginning of each mining step.

General information:

rec 1: `TITLE,NNT,NELT,NDIM,NPG,MSTEP`
rec 2: `(TIMEL(I),I=1,MSTEP)`
rec 3: `(VCORG(I), I =1,NNT*NDIM)`

for each element

next rec: `INEL`
next rec: `IE,(KNE(I),I=1,INEL),IGPE,KONE`

for each selected time step

`ICHK,ISTEP,TTIME`

for each node

`IN,V(1),V(2),FX(1),FX(2)`
`(VSTRS(I),I=1,2*NDIM*NPG)`
`(VSTRN(I),I=1,2*NDIM*NPG)`
`(VRATE(I),I=1,(2*NDIM+1)*NPG)`

for each element

`ISTAT,ICE,IPG,VPREE(4)`

`PDISP.DAT` tabbed format

A post-processor file containing x and y displacements at each time interval for a list of nodes (10 maximum) requested by the user. This can be imported into any x-y plotter.

`PSIGM.DAT` tabbed format

A post-processor file containing stresses σ_x and σ_y at each time interval for a list of elements (10 maximum) requested by the user. This can be imported into any x-y plotter.

2.1.2 Input Files

The name of the input file is given to the program and may contain up to 10 characters in the following format: XXXXXX.DAT

2.1.3 Output Files

The name of the output file is given to the program and may contain up to 10 characters in the following format: XXXXXX.OUT

2.2 Memory Allocation

2.2.1 Global Memory Specification

Dynamic memory allocation is not a standard feature of Fortran 77—memory requirements must therefore be specified before the program is compiled. VISROCK uses a global array "A" dimensioned before compilation. Sub-arrays can be dynamically allocated out of this global array. This uses the memory allocated as efficiently as possible; as an added advantage, the memory can be changed by altering one line of source code.
If the size of the global array is not sufficient for the problem being analyzed VISROCK will inform the user by printing an error message. It is then necessary to change the dimension of the global array "A". The value of the parameter NSIZE determines the dimension of "A" and is set in the main program of VISROCK on the parameter line shown below. Once the value of NSIZE has been changed, VISROCK has to be recompiled and linked together.

```
PARAMETER (NSIZE=800000)
```

2.2.2 Array Pointer and Handle Allocation

Sub-arrays are allocated space in the global array by a subroutine called ESPACE. ESPACE calculates an offset from the beginning of the global array and allocates the memory. If the memory for the sub-array cannot be allocated, ESPACE prints an error message and stops the analysis. To correct the error, the global memory allocation must be changed.

References

Cormeau, I., 1975. Numerical Stability in Quasistatic Elasto-visco-plasticity, Int. J. Num. Meth. Engng. vol 9, pp. 109-127.

Dhatt, G., Thouzot, G., Cantin, G., 1984. The Finite element Method Displayed, John Wiley & Sons, New-York, 509p.

Owen, D.R.J., Hinton, E., 1980. Finite Elements in Plasticity: Theory and Practice, Pineridge Press Limited, Swansea, U.K, 394p.

Wan, R.G , 1992. VISROCK: An Elasto-viscoplastic Program for Rocks, Theoretical Manual, CANMET. MRL report MRL 92-036

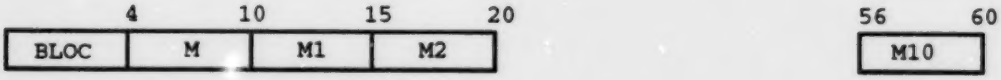
APPENDIX

INPUT DATA MANUAL

0.0 HEADING CARD

Format (A4,I6,10I5)

Each generic block must begin with a heading card with a keyword identifying the name of the block to execute and the peripheral files used within the block.

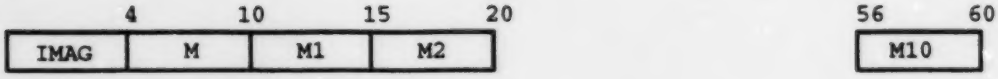


Variable		Default	Description
BLOC	:	----	Name of block to process
M	:	0	Level of intermediate printing (0<M<3)
			0 = production run
			1 = reduced printout
			2 = debugging printout
			3 = extended printout
M1	:	5	Logical read unit number
M2	:	----	
.		.	Logical unit number for files used in the bloc
.		.	
M10		.	

Note: All real numbers are read in format F10.X and integers in I5. Each specific block must start with the above heading card and is processed in the order they appear.

1.0 PRINT INITIATION BLOCK

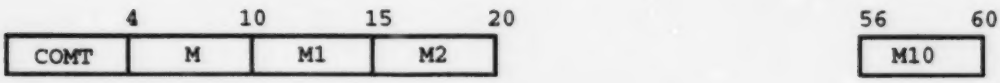
Format (A4,I6,10I5)



This block is optional and echoes the whole input data file for checking purposes. Note that whenever used, this block has to be the first processing block.

2.0 COMMENTS BLOCK

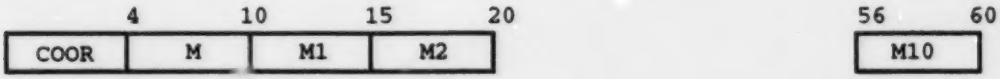
Format(A4,I6,10I5)



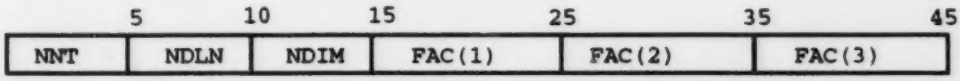
This block is used for placing commentary text anywhere in the data file. For example, it can be used to give a project title to the case being analyzed. Note that this block has to be a stand-alone block terminated by a blank line.

3.0 NODAL COORDINATES BLOCK

• Heading Card **Format (A4,I6,10I5)**



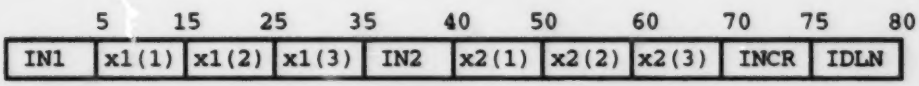
• Control Parameter Card **Format (3I5,3F10.0)**



Variable		Default	Description
NNT	:	8	Maximum total number of nodes
NDLN	:	2	Maximum number of degrees of freedom per node
NDIM	:	2	Dimension of problem (1,2,3). Note in this version both one and three dimensional geometries have been suppressed
FAC(1)	:	1.0	Scaling factor in x-direction (for unit conversion purposes)
FAC(2)	:	1.0	Scaling factor in y-direction (for unit conversion purposes)
FAC(3)	:	1.0	Scaling factor in z-direction (suppressed)

• Nodal Coordinates Card

Format (I5,3F10.0,I5,3F10.0,2I5)



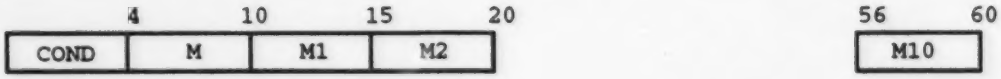
Variable		Default	Description
IN1	:	----	Node number of first node to generate
X1(1)	:	----	x-coordinate of this node
X1(2)	:	----	y-coordinate of this node
X1(3)	:	----	z-coordinate of this node
IN2	:	----	Node number of last node to generate
X2(1)	:	X1(1)	x-coordinate of this node
X2(2)	:	X1(2)	y-coordinate of this node

X2(3)	:	X1(3)	z-coordinate of this node
INCR	:	1	Increment of this node number for generation
IDLN	:	NDLN	Number of degrees of freedom to generate if different from NDLN (this option which is relevant only when 1-D elements are mixed with 2-D elements is not being used in this version)

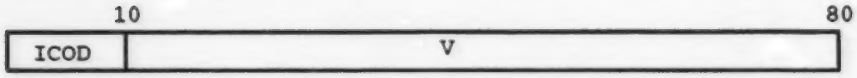
Note: The node and element generation is normally not used herein since it is expected that the mesh has been already generated by the pre-processor which comes with VISROCK. Use default values for X2(1), X2(2), X1(3) and IDLN unless mesh generation from internal program option is used. Also, the internal mesh generation works only for the construction of regular grids.

4.0 BOUNDARY CONDITIONS BLOCK

• **Heading Card** **Format (A4,I6,10I5)**

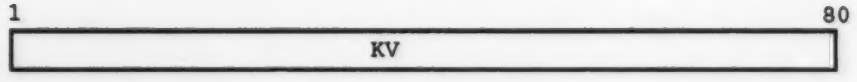


• **Fixity Card** **Format (10I1,7F10.0)**



Variable		Default	Description
ICOD	:	----	Fixity code for each degree of freedom (maximum 10) 1 : fixed 0 : free 2 : constrained to a value Note that the first and second degrees of freedom correspond to *x* and *y* displacements respectively
V	:	----	List of corresponding non-zero values assigned to constrained degrees of freedom, i.e imposed displacements

• **Constrained Nodes Card** **Format (16I5)**

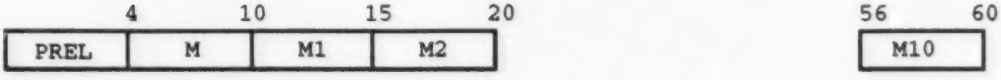


KV : ---- List of constrained nodes terminated by a **new line with two zero's**

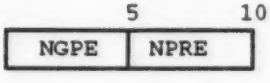
Note: The list of values V and KV can be extended to additional cards following the same original format, i.e 16I5.

5.0 ELEMENT PROPERTIES BLOCK

• **Heading Card** **Format (A4,I6,10I5)**



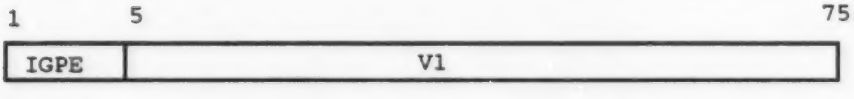
• **Element Control Card** **Format(2I5)**



Variable		Default	Description
NGPE	:	0	Number of element property groups
NPRE	:	0	Number of material parameters per property group

Now follows a suite of NGPE cards defining the material properties

• **Material Property Card** **Format(I5,7E10.5)**



IGPE	:	----	Group number
V1	:	----	Material parameters for group IGPE

Note: If NPRE >7, extension of list of values of V1 goes on next line following the format.(5X,7E10.5).

Elasto-Viscoplastic Model

There are in all 18 entries for the elasto-viscoplastic model. The implementation of viscoplasticity is patterned after the classical Perzyna-type model which is a straight-forward extension of inviscid plasticity to rate dependent case by postulating a flow rule based on a "plastic" potential and a fluidity parameter (inverse of viscosity) for time effects.

In this version of the program, the plastic potential coincides with the yield function and as such involves an associated flow rule. However, entry parameters such as dilatancy angles to define a plastic potential are reserved for future implementation of non-associated viscoplasticity.

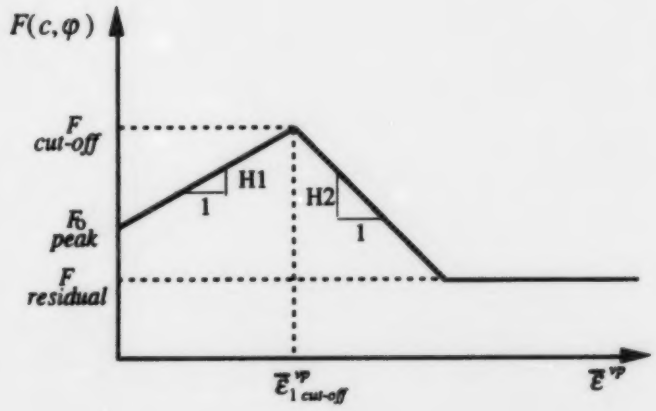
The onset of inelastic time dependent deformations is based on the choice on an empirical failure criterion represented by either von Mises, Mohr-Coulomb or Drucker-Prager function.

Variable		Default	Description
V(1)	:	1	Model type 1: Perzyna based Viscoplasticity 2 : Duvaut and Lions Viscoplasticity (not implemented yet)
V1(2)	:	2	Yield criterion on which onset of viscoplastic deformations 1: Mohr-Coulomb 2: Drucker-Prager 3: Tresca 4: von-Mises 5: Hoek-Brown (not implemented yet)
V1(3)	:	1	Thickness (m). This has meaning only for plane strain problems. For axi-symmetric case, analysis is performed for a sector of 1 radian for the solid under investigation
V1(4)	:	.02	Density in MN/m^3. For an excavation material, void, this entry has to be zero.
V1(5)	:	----	Young's Modulus in MPa.
V1(6)	:	.3	Poisson ratio
V1(7)	:	-----	Peak yield stress if yield criterion is of Tresca or von-Mises type, else peak cohesion for Mohr-Coulomb or Drucker-Prager type
V1(8)	:	V1(7)	Residual yield stress if yield criterion is of Tresca or von-Mises type, else residual cohesion for Mohr-Coulomb or Drucker-Prager type. This entry is used

			when hardening or softening of yield stress or cohesion is contemplated. Typically the residual value is .1 of the peak value
V1(9)	:	----	Peak friction angle in degrees for Mohr-Coulomb or Drucker-Prager type
V1(10)	:	V1(9)	Residual friction angle in degrees for Mohr-Coulomb or Drucker-Prager type if hardening or softening is contemplated
V1(11)	:	V1(9)	Peak dilatancy angle in degrees for Mohr-Coulomb or Drucker-Prager type if non-assocaited viscoplasticity is used
V1(12)	:	V1(11)	Residual dilatancy angle in degrees for Mohr-Coulomb or Drucker-Prager type if non-assocaited viscoplasticity with hardening/softening is used. Typically dilation angle starts with a high value at first and tends to zero in the ultimate range

Hardening/softening or perfect viscoplasticity description:

Strength (cohesion, yield stress or friction and dilation angles) degradation or hardening with effective viscoplastic strains can be described by a simple bilinear law as illustrated below:



V1(13)	:	0	Hardening modulus H1 in MPa as defined in the above figure. Softening is prescribed by a negative value
V1(14)	:	0	Hardening modulus H2 in MPa as defined in the above

figure. Softening is prescribed by a negative value

V1(15) : 10 Effective viscoplastic strain cut-off describing the transition from H1 to H2 (see above figure)

V1(16) : --- Fluidity parameter (/unit time). This parameter describes the rate at which viscoplastic deformations take place and is the inverse of viscosity. The generic viscoplastic flow rule is given by:

$$\dot{\varepsilon}^{vp} = \gamma\langle\Phi(F)\rangle\frac{\partial F}{\partial \sigma}$$

γ : fluidity parameter

$\Phi(F)$: basic creep law

For potash, the value of γ is found to be in the range of 10^{-4}-10^{-6} if the unit day is used for time

V1(17) : 1 The basic creep law can either follow a power law (1) or exponential decay (2) of the following form:

$$\Phi(F) = \begin{cases} \left(\frac{F}{F_0}\right)^n & (1) \\ e^{\left(\frac{F}{F_0}\right)^n} & (2) \end{cases}$$

The power law is the form most commonly used

V1(18) : 1 Exponent number *n*. Note that *n* cannot take any arbitrarily large value especially for the case of the exponential law. It is found that the range is between 1 and 5 for potash

6.0 ELEMENT CONNECTIVITY BLOCK

• **Heading Card** **Format (A4,I6,10I5)**

ELEM	M	M1	M2	M10

• **Element Control Card** **Format (6I5)**

5	10	15	20	25	30
NELT	NNEL	NTPE	NGRE	NSYM	NIDENT

Variable		Default	Description
NELT	:	----	Maximum number of elements
NNEL	:	8	Maximum number of nodes per element
NTPE	:	1	Element type number
			16: plane stress element
			17: plane strain element
			18: axisymmetric element
NGRE	:	1	Element group number
NSYM	:	0	Stiffness matrix symmetry:
			0 : symmetrical
			1 : non-symmetrical
NIDENT	:	0	Equals 1 if all stiffness matrices are identical

Now follows a suite of NELT element information cards terminated by IEL < 0.

• **Element Control Card** **Format (6I5,10I5)**

5	10	15	20	25	30	80
IEL	IGEN	INCR	ITPE	IGPE	IGRE	KNE

Variable		Default	Description
IEL	:	----	Number of first element
IGEN	:	1	Number of elements to generate starting from IEL

INCR	:	1	Node generation increment
ITPE	:	NTPE	Element type number if different from NTPE
IGPE	:	1	Element property group
IGRE	:	1	Element group
KNE	:	----	Element connectivity

7.0 INITIAL STRESS BLOCK

• Heading Card **Format (A4,I6,10I5)**

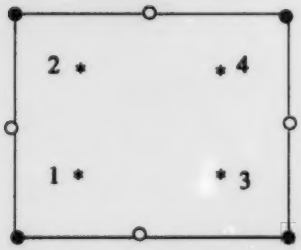
ISTR	M	M1	M2	M10

• Initial Stress Control Card **Format (I5)**

5

IOPT

Variable		Default	Description
IOPT	:	1	1: Initial stresses are given at the centroid of the element 2: Initial stresses are given at the 4 Gauss points ordered as follows



• Initial Stress Values Card **Format (I5,4E15.4)**

For each element:

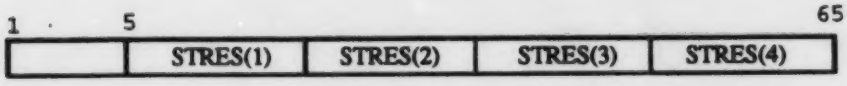
1 5 65

IEL	STRES(1)	STRES(2)	STRES(3)	STRES(4)

Variable		Default	Description
IEL	:	----	Element number
STRES(1)			Stress σ_{xx} in the x-x direction
STRES(2)			Stress σ_{yy} in the y-y direction

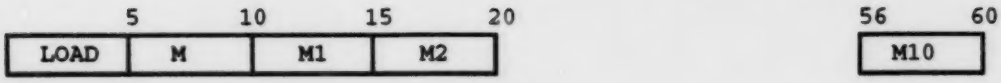
STRES(3)	Stress σ_{xy} in the x-y direction
STRES(4)	Stress σ_{zz} in the z-z direction

If IOPT 2 is used, the next 3 records will contain the stress components at remaining three Gauss points in format (5X,4E15.4).

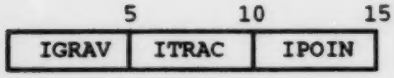


8.0 LOAD BLOCK

• **Heading Card** **Format (A4,I6,10I5)**



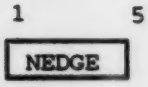
• **Load Control Card** **Format (3I5)**



Variable		Default	Description
IGRAV	:	----	1 : Gravity loading (vertical direction only)
			0 : No gravity
ITRAC	:	----	1 : Boundary tractions
			0 : No boundary tractions
IPOIN	:	----	1 : Point loads
			0 : No point loads

If ITRAC is 1

• **Load Control Card** **Format (I5)**



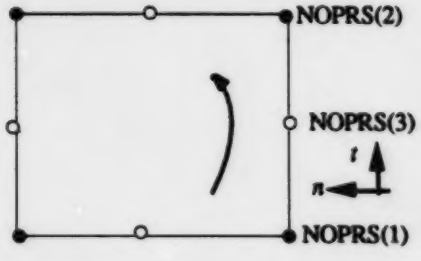
Variable		Default	Description
NEDGE	:	----	Number of edges on which tractions are applied

For NEDGE *edges*

• **Edge Definition Card** **Format (4I5)**

5	10	15	20
NEASS	NOPRS(1)	NOPRS(2)	NOPRS(3)

Variable		Default	Description
NEASS	:	----	Element to which tractions are applied
NOPRS(1)	:	----	Global node number of first node on edge along which traction is applied
NOPRS(2)	:	----	Global node number of last node on edge along which traction is applied
NOPRS(3)	:	0	Global node number of mid node on edge along which traction is applied



• Tractions Definition Card **Format (6F10.3)**

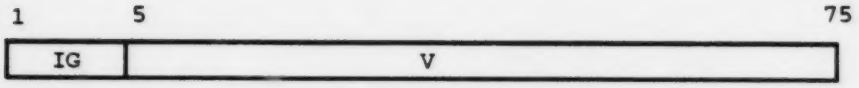
10	20	30	40	50	60
PRESS(1,1)	PRESS(1,2)	PRESS(2,1)	PRESS(2,2)	PRESS(3,1)	PRESS(3,2)

Variable		Default	Description
PRESS(1,1)	:	----	Normal traction acting at node NOPRS(1)
PRESS(1,2)	:	----	Tangential traction acting at node NOPRS(1)
PRESS(2,1)	:	----	Normal traction acting at node NOPRS(2)
PRESS(2,2)	:	----	Tangential traction acting at node NOPRS(2)
PRESS(3,1)	:	0.0	Normal traction acting at node NOPRS(3)
PRESS(3,2)	:	0.0	Tangential traction acting at node NOPRS(3)

Note: The sign convention used follows a positive number for compression if nodes are entered in an anticlockwise manner as illustrated in the above figure. For 4-node elements, leave blanks for the mid node entries.

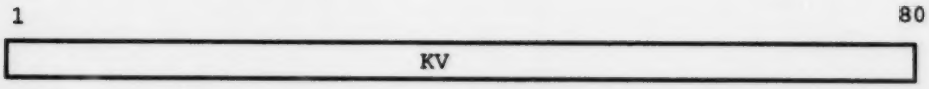
If IPOIN is 1

• Point Load Card **Format (I5,7E10.2)**



Variable		Default	Description
IG	:	----	Group number of nodes at which point loads are applied
V	:	----	Point load values to be applied at each degree of freedom

• Node List Card **Format (16I5)**



KV	:	----	List of nodes at which above point loads are to be applied

List KV can be extended by using additional lines each of format 16I5. Terminate the point load section by a blank line or a negative number. Note this termination line is not needed when whenever there is gravity loading or external tractions.

9.0 VISP BLOCK

• Heading Card **Format (A4,I6,10I5)**

5	10	15	20	56	60
VISP	M	M1	M2	M10	

• Print Control Card **Format (4I5)**

5	10	15	20
IN(1)	IN(2)	IN(3)	IN(4)

Variable		Default	Description
IN(1)	:	0	Restart indicator 0: Normal run 1: Restart run. Note that restart takes place at two time steps prior to time at which breakdown or interruption was done. The restart file contains data for the last two time steps and is contained in RESTART.DAT
IN(2)	:	0	Flag for stress, strain and displacement print out 0 : no printout 1 : stress, strain, displacement printed for all elements
IN(3)	:	1 IN(2)>0	Frequency of print out (displacement and stresses) if
IN(4)	:	0	Flag for residue and reactions printout (not used)

• Time Integration Parameter Card **Format (2I5,6F10.0)**

5	10	20	30	40	50	60	70
MSTEP	IOPT	FINAL	ALPHA	TAUFT	DTINT	FTIME	TOLER

Variable		Default	Description
MSTEP	:		Total number of mining/load steps
IOPT	:	1	Initial stress calculation option

1: Initial stresses are read or calculated in step 0
0: No initial stress

FINAL : ---- Final time of analysis

ALPHA : 0.0 Integration scheme parameter which takes a value between 0 1 and 1
0: Explicit time integration (stiffness is not updated)
1: Fully implicit time integration

TAUFT : .05 Time step controller based on effective viscoplastic strains as follows

$$\Delta t_{n+1} \leq \tau \left(\frac{\bar{\varepsilon}_{n+1}}{\bar{\varepsilon}^{vp}_{n+1}} \right)_{\min}$$

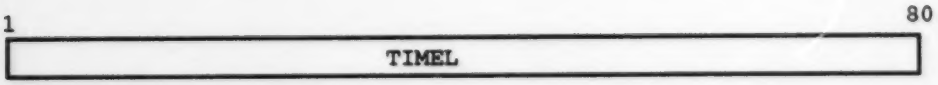
DTINT : .1 Initial time step

FTIME : 1.5 Time step limiter based on previous time step
$\Delta t_{n+1} \leq k \Delta t_n$

TOLER : 10^{-5} Tolerance to determine attainment of steady state

If MSTEP >0

- **Mining Times Card** **Format (8F10.5)**



TIMEL : ---- List of times at which mining takes place. Additional cards can be added to number of mining steps greater than 8

- **Node History Card** **Format (10I5)**

LISTD : ---- List of nodes (limited to 10) for which displacement history is to be recorded for plotting. Note that x and y displacements at every time interval will be recorded in tabbed format for selected nodes in post-processor file

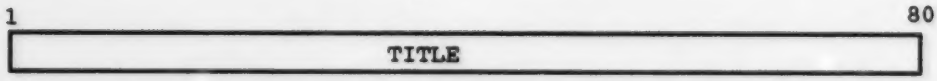
PDISP.DAT. If no node history is needed enter a blank line

- **Element Stress History Card** **Format (10I5)**

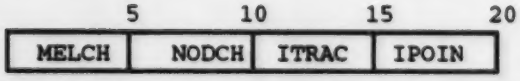
LISTS : ---- List of elements (limited to 10) for which stress history is to be recorded for plotting. Note that only averaged values of σ_x and σ_y at the centroid of the element at every time interval will be recorded in tabbed format for selected elements in post processor file PSIGM.DAT. If no stress history is needed enter a blank line

For each mining step

- **Title Card** **Format (20A4)**



- **Mining Step Control Card** **Format (4I5)**

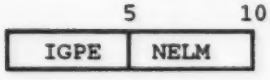


Variable		Default	Description
MELCH	:	---	Number of group of elements whose information have to be changed during this step
NODCH	:	---	Number of nodes added or removed during this step
ITRAC	:	0	Flag for incremental boundary tractions for this step
IPOIN	:	0	Flag for incremental point loads for this step

If MELCH>0

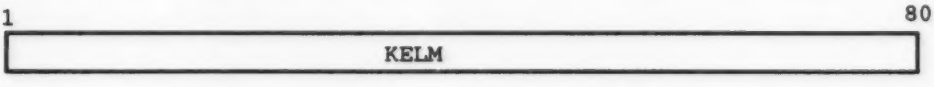
For each MELCH

- **Material Property Group Change Card Format (2I5)**



IGPE : --- New material property group (backfill or void)
NELM : --- Number of elements whose property is changed

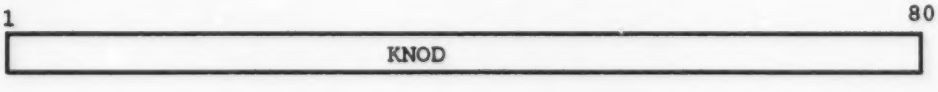
- **List of Element Property Change Card Format (16I5)**



KELM : --- List of elements whose property are changed

If NODCH>0

- **List of Nodal Change Card Format (16I5)**



KNOD : --- List of nodes to be added or removed during this step

If ITRAC>0

read incremental tractions as in previous load section

If IPOIN>0

read incremental point loads as in previous load section

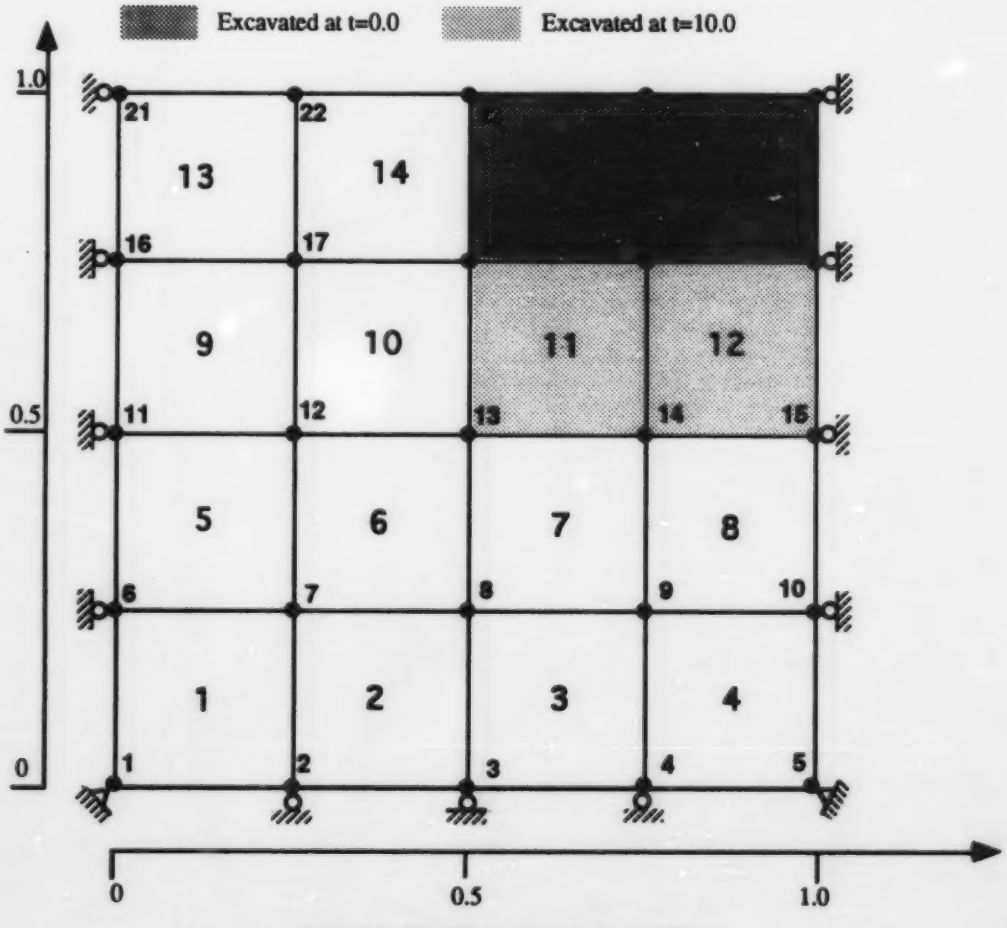
10.0 CLOSURE BLOCK

Terminate data file by a `STOP`

EXAMPLE

A very simple numerical example is presented to show the input data information which is read from VISROCK. This input file can be alternatively produced by the pre-processor (described in another manual) which generates the mesh data as well as information pertinent to material properties and excavation sequence.

The following example is concerned with a regular mesh made up of 16 elements and 25 nodes in which elements are removed in such a way to simulate as closely as possible an excavation sequence.



Sample Problem for Excavation

SAMPLE INPUT

```
IMAG
CONT
Refined mesh for staged excavation (25nodes x 16elems)

COOR     0    0    0
   25    2    2
    1  0.000         0.00          0.0   5    1.0          0.00          0.0   1
    6  0.000         0.25          0.0  10    1.0          0.25          0.0   1
   11  0.000         0.50          0.0  15    1.0          0.50          0.0   1
   16  0.000         0.75          0.0  20    1.0          0.75          0.0   1
   21  0.000         1.00          0.0  25    1.0          1.00          0.0   1
   -1
COND     3
11                0.0          0.0
    1    5
01                0.0          0.0
    2    3    4
10                0.0          0.0
    6   10   11   15   16   20   21   25
00
PREL     0
    2   18
    1        1.0          2.0          1.0       0.2E-1       0.1E+1         0.4       0.1E-3
           0.1E-3         20.0         20.0         20.0         20.0         0.0          0.0
             10.0       0.1E-2          1.0          1.0
    2        1.0          2.0          1.0          0.0          0.0          0.0          0.0
             0.0          0.0          0.0          0.0          0.0          0.0          0.0
             0.0          0.0          0.0          0.0
   -1
ELEM     0    1    0
   16    4   17    1    0
    1
    1    4    1   17    1    1    1    2    7    6    0    0    0    0
    5    4    1   17    1    1    6    7   12   11    0    0    0    0
    9    4    1   17    1    1   11   12   17   16    0    0    0    0
   13    4    1   17    1    1   16   17   22   21    0    0    0    0
   -1
LOAD     0    1
GRAVITY LOADS ONLY
    1
VISP     0    1    2    3    4    7
    0    1    1
    2    1   500.     0.5         0.05          0.01          1.5       0.1E-9
  0.0         10.0
***STEP 1 (t=0): excavate element 15,16****
    1    2    0
    2    2
   15   16
   24   25
***STEP 2 (t=10): excavate element 11,12****
    1    2    0
    2    2
   11   12
   19   20
STOP
```

SAMPLE OUTPUT (showing partial results at selected times)

```
1                              V I S R O C K

                  AN ELASTO-VISCOPLASTIC FINITE ELEMENT PROGRAM
                     CANMET: MINING RESEARCH LABORATORIES


 ECHO OF INPUT DATA
 ==================

                                                  C O L U M N   N U M B E R
 CARD          1         2         3         4         5         6         7         8
 NUMBER 12345678901234567890123456789012345678901234567890123456789012345678901234567890
 --------------------------------------------------------------------------------------------
       1  CONT
       2  Refined mesh for staged excavation (25nodes x 16elems)
       3
       4  COOR     0    0    0
       5     25    2    2
       6        1  0.000          0.00          0.0   5    1.0          0.00          0.0   1
       7        6  0.000          0.25          0.0  10    1.0          0.25          0.0   1
       8       11  0.000          0.50          0.0  15    1.0          0.50          0.0   1
       9       16  0.000          0.75          0.0  20    1.0          0.75          0.0   1
      10       21  0.000          1.00          0.0  25    1.0          1.00          0.0   1
      11       -1
      12  COND     0
      13  11                  0.0         0.0
      14        1    5
      15  01                  0.0         0.0
      16        2    3    4
      17  10                  0.0         0.0
      18        6   10   11   15   16   20   21   25
      19  00
      20  PREL     0
      21        2   18
      22        1       1.0         2.0         1.0     0.2E-1     0.1E+1         0.4     0.1E-3
      23              0.1E-3        20.0        20.0       20.0       20.0         0.0        0.0
      24                1.0.0     0.1E-2         1.0        1.0
      25        2       1.0         2.0         1.0        0.0        0.0         0.0        0.0
      26                0.0         0.0         0.0        0.0        0.0         0.0        0.0
      27                0.0         0.0         0.0        0.0
      28       -1
      29  ELEM     0    1    0
      30     16    4   17    1    0
      31        1
      32        1    4    1   17    1    1    1    2    7    6    0    0    0    0
      33        5    4    1   17    1    1    6    7   12   11    0    0    0    0
      34        9    4    1   17    1    1   11   12   17   16    0    0    0    0
      35       13    4    1   17    1    1   16   17   22   21    0    0    0    0
      36       -1
      37  LOAD     0    1
      38  GRAVITY LOADS ONLY
      39        1
      40  VISP     0    1    2    3    4    7
 --------------------------------------------------------------------------------------------
 CARD          1         2         3         4         5         6         7         8
 NUMBER 12345678901234567890123456789012345678901234567890123456789012345678901234567890
                                                  C O L U M N   N U M B E R
1


                                                  C O L U M N   N U M B E R
 CARD          1         2         3         4         5         6         7         8
 NUMBER 12345678901234567890123456789012345678901234567890123456789012345678901234567890
 --------------------------------------------------------------------------------------------
      41        0    1    1                                                  4
      42        2    1   500.    0.5      0.05      0.01       1.5    0.1E-9
      43      0.0      10.0
      44  ***STEP 1 (t=0): excavate element 15,16****
      45        1    2    0
      46        2    2
      47       15   16
      48       24   25
      49  ***STEP 2 (t=10): excavate element 11,12****
      50        1    2    0
      51        2    2
      52       11   12
      53       19   20
      54  STOP
 --------------------------------------------------------------------------------------------
 CARD          1         2         3         4         5         6         7         8
 NUMBER 12345678901234567890123456789012345678901234567890123456789012345678901234567890
                                                  C O L U M N   N U M B E R
```

```
                                        E N D   O F   I N P U T
1

 TITLE OF PROJECT
 ================

 Refined mesh for staged excavation (25nodes x 16elems)

 NODAL INFORMATION (N= 0)
 ========================
              MAXIMUM NUMBER OF NODES              (MNT)=   25
              MAXIMUM NUMBER OF DOF PER NODE      (NDLN)=    2
              DIMENSION OF PROBLEM                (NDIM)=    2
              CONTROL PARAMETER TO PRINT RESULTS  (NIMP)=   -1
              SCALING FACTOR FOR COORDINATES       (FAC)= 0.10000E+01 0.10000E+01 0.10000E+01
              SIZE OF BLANK COMMON                 (NVA)=    800000


 BOUNDARY CONDITIONS (N= 0)
 ==========================

 >>>>>          1   5   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 >>>>>          2   3   4   0   0   0   0   0   0   0   0   0   0   0   0   0
 >>>>>          6  10  11  15  16  20  21  25   0   0   0   0   0   0   0   0

              TOTAL NUMBER OF NODES                    (MNT)=   25
              TOTAL NUMBER OF DEGREES OF FREEDOM       (NDLT)=   50
              NUMBER OF ACTIVE UNKNOWNS                 (NEQ)=   35
              NUMBER OF NON-ZERO IMPOSED DOF          (NCLNZ)=    0
              NUMBER OF IMPOSED ZERO DOF               (NCLZ)=   15
              TOTAL NUMBER OF IMPOSED DOF              (NCLT)=   15


 ELEMENT PROPERTIES INFORMATION (N= 0)
 =====================================
              NO. OF MATERIAL PROPERTY GROUPS      (NGPE)=    2
              NO. OF PARAMETERS PER MATERIAL GROUP  (NPRE)=   18

 ELEMENT PROPERTY CARDS


 ELEMENT  INFORMATION (N= 0)
 ===========================
              MAXIMUM NUMBER OF ELEMENTS        (NELT)=   16
              MAX. NO. OF NODES PER ELEMENT     (NNEL)=    4
              ELEMENT TYPE (BY DEFAULT)         (NTPE)=   17
              NUMBER OF ELEMENT GROUPS          (NGRE)=    1
              FLAG FOR NON-SYMMETRY             (NSYM)=    0
              FLAG FOR IDENTICAL ELEMENTS     (NIDENT)=    0


   ELEMENTS WHOSE STRESSES ARE TO BE PRINTED:


              MEAN HEIGHT OF BAND =     8.2 MAXIMUM =   11
              NO. OF ELEMENTS IN UPPER DIAGONAL KG   (NKG)=       287
              TOTAL NUMBER OF INTEGRATION POINTS     (NPG)=        64


 ASSEMBLY OF EXTERNAL FORCES (N= 0)
 ==================================


 ELASTO-VISCOPLASTIC ANALYSIS (N= 0)
 ===================================
 FILES USED IN THIS ANALYSIS:    1    2    3    4

               FLAG FOR RESTART CALCULATION    (NRES)=    0
                   NRES=0 : NORMAL RUN
                   NRES=1 : RESTART RUN
               PRINT FLAGS:
               STRESS & STRAINS =    1
               SOLUTION =    1
               REACTIONS ET RESIDUALS =    0
1              SOLUTION OF ELASTO-VISCOPLASTIC PROBLEM IN 2-D

     STRESS CONDITION                  (NTYPE) =    1
                 NTYPE: 0 PLANE STRESS
                 NTYPE: 1 PLANE STRAIN
```

```
                NTYPE: 2 AXISYMMETRY

    NUMBER OF MINING STEPS            (MSTEP) =    2
    OPTION FOR INTIAL STRESSES        (IOPT)  =    1
              IOPT: 0 NO INITIAL STRESSES
              IOPT: 1 SWITCH ON GRAVITY

    FINAL TIME OF ANALYSIS            (FINAL) = 0.50000E+03
    TIME INTEGRATION PARAMETER        (ALPHA) = 0.50000E+00
    FACTOR TAU TO LIMIT TIME STEP     (TAUFT) = 0.50000E-01
    INITIAL TIME INTERVAL             (DTINT) = 0.10000E-01
    CRITICAL TIME FACTOR K            (FTIME) = 0.15000E+01
    TOLERANCE CHECK FOR STEADY STATE  (TOLER) = 0.10000E-09


 MINING ACTIVITY TIMES ARE:
   0.00000  10.00000

 ELEMENT PROPERTY GROUP    1
              MODEL TYPE                              = 1.
              YIELD CRITERION                         = 2.
                   MOHR-COULOMB :1
                 DRUCKER-PRAGER :2
                        TRESCA :3
                     VON-MISES :4
              THICKNESS                        (m)    = 0.10000E+01
              DENSITY                     (MN/m^3)    = 0.20000E-01
              YOUNG'S MODULUS               (MPa)     = 0.10000E+01
              POISSON RATIO                           = 0.40000E+00
              PEAK YIELD STRESS/COHESION    (MPa)     = 0.10000E-03
              RESIDUAL YIELD STRESS/COHESION (MPa)    = 0.10000E-03
              PEAK FRICTION ANGLE           (deg)     = 0.20000E+02
              RESIDUAL FRICTION ANGLE       (deg)     = 0.20000E+02
              PEAK DILATION ANGLE           (deg)     = 0.20000E+02
              RESIDUAL DILATION ANGLE       (deg)     = 0.20000E+02
              HARDENING MODULUS H1          (MPa)     = 0.00000E+00
              HARDENING MODULUS H2          (MPa)     = 0.00000E+00
              EFFECTIVE PLASTIC STRAIN CUT-OFF        = 0.10000E+02

              FLUIDITY PARAMETER       /unit Time     = 0.10000E-02
              REGULARIZATION FUNCTION                 = 1.

                   EXPONENTIAL:(0)
                   POWER LAW  :(1)
              EXPONENT NUMBER                         = 0.10000E+01


 ELEMENT PROPERTY GROUP    2
              MODEL TYPE                              = 1.
              YIELD CRITERION                         = 2.
                   MOHR-COULOMB :1
                 DRUCKER-PRAGER :2
                        TRESCA :3
                     VON-MISES :4
              THICKNESS                        (m)    = 0.10000E+01
              DENSITY                     (MN/m^3)    = 0.00000E+00
              YOUNG'S MODULUS               (MPa)     = 0.00000E+00
              POISSON RATIO                           = 0.00000E+00
              PEAK YIELD STRESS/COHESION    (MPa)     = 0.00000E+00
              RESIDUAL YIELD STRESS/COHESION (MPa)    = 0.00000E+00
              PEAK FRICTION ANGLE           (deg)     = 0.00000E+00
              RESIDUAL FRICTION ANGLE       (deg)     = 0.00000E+00
              PEAK DILATION ANGLE           (deg)     = 0.00000E+00
              RESIDUAL DILATION ANGLE       (deg)     = 0.00000E+00
              HARDENING MODULUS H1          (MPa)     = 0.00000E+00
              HARDENING MODULUS H2          (MPa)     = 0.00000E+00
              EFFECTIVE PLASTIC STRAIN CUT-OFF        = 0.00000E+00

              FLUIDITY PARAMETER       /unit Time     = 0.00000E+00
              REGULARIZATION FUNCTION                 = 0.

                   EXPONENTIAL:(0)
                   POWER LAW  :(1)
              EXPONENT NUMBER                         = 0.00000E+00

time and step:  0.  0


 S O L U T I O N
 ***************

 TIME STEP NUMBER         0
 TOTAL TIME IS 0.00000E+00


              ENERGY    (ENERG)= 0.61250E-04

              SMALLEST PIVOT (ABSOLUTE VALUE)  = 0.35630E+00 EQUATION:   35
                          ALGEBRAIC VALUE = 0.35630E+00 EQUATION:   35
                          DETERMINANT= 0.10131E+09 * 10 **      0
```

```
   ooooo STEADY STATE CONDITIONS HAVE BEEN ACHIEVED, END OF TIME:    0.00000E+00
   NORM OF RESIDUAL SUM RATIO =  0.000000E+00

FIRST ESTIMATE OF DNEXT,DTIME,FTIME:  0.  0.    1.5000000000000
FINAL DTIME FOR STEP:  0  0.

 NODES     X           Y           Z          DISPLACEMENTS   (*   = IMPOSED)

     1 0.00000E+00 0.00000E+00 0.00000E+00      0.00000E+00 *   0.00000E+00 *
     2 0.25000E+00 0.00000E+00 0.00000E+00      0.83669E-19     0.00000E+00 *
     3 0.50000E+00 0.00000E+00 0.00000E+00      0.48895E-18     0.00000E+00 *
     4 0.75000E+00 0.00000E+00 0.00000E+00      0.35237E-18     0.00000E+00 *
     5 0.10000E+01 0.00000E+00 0.00000E+00      0.00000E+00 *   0.00000E+00 *
     6 0.00000E+00 0.25000E+00 0.00000E+00      0.00000E+00 *  -0.20417E-02
     7 0.25000E+00 0.25000E+00 0.00000E+00      0.10842E-18    -0.20417E-02
     8 0.50000E+00 0.25000E+00 0.00000E+00      0.20329E-18    -0.20417E-02
     9 0.75000E+00 0.25000E+00 0.00000E+00      0.33881E-18    -0.20417E-02
    10 0.10000E+01 0.25000E+00 0.00000E+00      0.00000E+00 *  -0.20417E-02
    11 0.00000E+00 0.50000E+00 0.00000E+00      0.00000E+00 *  -0.35000E-02
    12 0.25000E+00 0.50000E+00 0.00000E+00     -0.12875E-18    -0.35000E-02
    13 0.50000E+00 0.50000E+00 0.00000E+00      0.54210E-19    -0.35000E-02
    14 0.75000E+00 0.50000E+00 0.00000E+00     -0.10842E-18    -0.35000E-02
    15 0.10000E+01 0.50000E+00 0.00000E+00      0.00000E+00 *  -0.35000E-02
    16 0.00000E+00 0.75000E+00 0.00000E+00      0.00000E+00 *  -0.43750E-02
    17 0.25000E+00 0.75000E+00 0.00000E+00     -0.87160E-18    -0.43750E-02
    18 0.50000E+00 0.75000E+00 0.00000E+00     -0.78605E-18    -0.43750E-02
    19 0.75000E+00 0.75000E+00 0.00000E+00     -0.65052E-18    -0.43750E-02
    20 0.10000E+01 0.75000E+00 0.00000E+00      0.00000E+00 *  -0.43750E-02
    21 0.00000E+00 0.10000E+01 0.00000E+00      0.00000E+00 *  -0.46667E-02
    22 0.25000E+00 0.10000E+01 0.00000E+00     -0.84026E-18    -0.46667E-02
    23 0.50000E+00 0.10000E+01 0.00000E+00     -0.14162E-17    -0.46667E-02
    24 0.75000E+00 0.10000E+01 0.00000E+00     -0.81315E-18    -0.46667E-02
    25 0.10000E+01 0.10000E+01 0.00000E+00      0.00000E+00 *  -0.46667E-02
time and step:  0.  1


***STEP 1 (t=0): excavate element 15,16****


***THESE ELEMENTS ARE CHANGED TO MATERIAL GROUP  2
   15   16


***THESE NODES HAVE BEEN ADDED OR DELETED:
   24   25


 S O L U T I O N
 ***************

 TIME STEP NUMBER         1
 TOTAL TIME IS 0.00000E+00


              ENERGY     (ENERG)= 0.43263E-05

              SMALLEST PIVOT (ABSOLUTE VALUE)  = 0.37230E+00 EQUATION:   32
                           ALGEBRAIC VALUE = 0.37230E+00 EQUATION:   32
                           DETERMINANT= 0.13636E+07 * 10 **      0


   ----- THERE IS A DECREASE IN THE RESIDUAL ERROR, END OF TIME:    0.00000E+00
   NORM OF RESIDUAL SUM RATIO =  0.100000E+01

FIRST ESTIMATE OF DNEXT,DTIME,FTIME:  0.  0.    1.5000000000000
FINAL DTIME FOR STEP:  1    1.00000000000000D-02

 NODES     X           Y           Z          DISPLACEMENTS   (*   = IMPOSED)

     1 0.00000E+00 0.00000E+00 0.00000E+00      0.00000E+00 *   0.00000E+00 *
     2 0.25000E+00 0.00000E+00 0.00000E+00      0.27793E-03     0.00000E+00 *
     3 0.50000E+00 0.00000E+00 0.00000E+00      0.40469E-03     0.00000E+00 *
     4 0.75000E+00 0.00000E+00 0.00000E+00      0.29317E-03     0.00000E+00 *
     5 0.10000E+01 0.00000E+00 0.00000E+00      0.00000E+00 *   0.00000E+00 *
     6 0.00000E+00 0.25000E+00 0.00000E+00      0.00000E+00 *  -0.82391E-04
     7 0.25000E+00 0.25000E+00 0.00000E+00      0.28879E-03     0.98588E-05
     8 0.50000E+00 0.25000E+00 0.00000E+00      0.43059E-03     0.26783E-03
     9 0.75000E+00 0.25000E+00 0.00000E+00      0.31534E-03     0.57854E-03
    10 0.10000E+01 0.25000E+00 0.00000E+00      0.00000E+00 *   0.70327E-03
    11 0.00000E+00 0.50000E+00 0.00000E+00      0.00000E+00 *  -0.19377E-03
    12 0.25000E+00 0.50000E+00 0.00000E+00      0.28465E-03    -0.20991E-04
    13 0.50000E+00 0.50000E+00 0.00000E+00      0.45135E-03     0.50056E-03
    14 0.75000E+00 0.50000E+00 0.00000E+00      0.34650E-03     0.12130E-02
    15 0.10000E+01 0.50000E+00 0.00000E+00      0.00000E+00 *   0.14754E-02
    16 0.00000E+00 0.75000E+00 0.00000E+00      0.00000E+00 *  -0.28904E-03
    17 0.25000E+00 0.75000E+00 0.00000E+00      0.15347E-03    -0.80288E-04
    18 0.50000E+00 0.75000E+00 0.00000E+00      0.26432E-03     0.68577E-03
    19 0.75000E+00 0.75000E+00 0.00000E+00      0.95823E-04     0.19518E-02
    20 0.10000E+01 0.75000E+00 0.00000E+00      0.00000E+00 *   0.21745E-02
    21 0.00000E+00 0.10000E+01 0.00000E+00      0.00000E+00 *  -0.31286E-03
    22 0.25000E+00 0.10000E+01 0.00000E+00     -0.42862E-04    -0.79865E-04
    23 0.50000E+00 0.10000E+01 0.00000E+00      0.21052E-03     0.39220E-03
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```
 24 0.75000E+00 0.10000E+01 0.00000E+00      0.00000E+00      0.00000E+00
 25 0.10000E+01 0.10000E+01 0.00000E+00      0.00000E+00 *    0.00000E+00

                S T R E S S E S   AND   S T R A I N S

ELEMENT NUMBER: 11

 G.P      SIG XX          SIG YY          TAU XY          SIG ZZ
VISCO-    EPS XX          EPS YY          GAM XY          EPS ZZ
PLASTIC   RATE XX         RATE YY         RATE XY         RATE ZZ        EFF.RATE

   1   -0.42871E-02    -0.55856E-02    0.89846E-03    -0.39491E-02
        0.00000E+00     0.00000E+00    0.00000E+00     0.00000E+00
        0.00000E+00     0.00000E+00    0.00000E+00     0.00000E+00     0.00000E+00
   2   -0.46021E-02    -0.57956E-02    0.13551E-02    -0.41591E-02
        0.00000E+00     0.00000E+00    0.00000E+00     0.00000E+00
        0.00000E+00     0.00000E+00    0.00000E+00     0.00000E+00     0.00000E+00
   3   -0.24606E-02    -0.28460E-02    0.84596E-03    -0.21226E-02
        0.00000E+00     0.00000E+00    0.00000E+00     0.00000E+00
        0.00000E+00     0.00000E+00    0.00000E+00     0.00000E+00     0.00000E+00
   4   -0.27756E-02    -0.30559E-02    0.13026E-02    -0.23326E-02
        0.00000E+00     0.00000E+00    0.00000E+00     0.00000E+00
        0.17995E-04     0.34881E-05    0.13481E-03     0.40918E-04     0.00000E+00

                S T R E S S E S   AND   S T R A I N S

ELEMENT NUMBER: 14

 G.P      SIG XX          SIG YY          TAU XY          SIG ZZ
VISCO-    EPS XX          EPS YY          GAM XY          EPS ZZ
PLASTIC   RATE XX         RATE YY         RATE XY         RATE ZZ        EFF.RATE

   1   -0.81097E-03    -0.22234E-02    0.76818E-03    -0.12137E-02
        0.00000E+00     0.00000E+00    0.00000E+00     0.00000E+00
        0.10800E-02    -0.57899E-03    0.18046E-02     0.60692E-03     0.00000E+00
   2   -0.10562E-03    -0.17531E-02    0.52569E-03    -0.74350E-03
        0.00000E+00     0.00000E+00    0.00000E+00     0.00000E+00
        0.20745E-02    -0.11684E-02    0.20695E-02     0.81894E-03     0.00000E+00
   3   -0.17809E-02    -0.36783E-02    0.88573E-03    -0.21837E-02
        0.00000E+00     0.00000E+00    0.00000E+00     0.00000E+00
        0.27583E-03    -0.17394E-03    0.41992E-03     0.18036E-03     0.00000E+00
   4   -0.10756E-02    -0.32081E-02    0.64325E-03    -0.17134E-02
        0.00000E+00     0.00000E+00    0.00000E+00     0.00000E+00
        0.10710E-02    -0.68485E-03    0.10593E-02     0.54577E-03     0.00000E+00

S O L U T I O N
***************

TIME STEP NUMBER          2
TOTAL TIME IS 0.10000E-01

              ENERGY     (ENERG)= 0.11220E-10

              SMALLEST PIVOT (ABSOLUTE VALUE)  = 0.37150E+00 EQUATION:   32
                           ALGEBRAIC VALUE = 0.37150E+00 EQUATION:   32
                           DETERMINANT= 0.13152E+07 * 10 **     0

  ----- THERE IS A DECREASE IN THE RESIDUAL ERROR, END OF TIME:     0.10000E-01
  NORM OF RESIDUAL SUM RATIO =  0.121188E-02

NODES     X           Y           Z          DISPLACEMENTS   (*  = IMPOSED)

    1 0.00000E+00 0.00000E+00 0.00000E+00      0.00000E+00 *    0.00000E+00 *
    2 0.25000E+00 0.00000E+00 0.00000E+00      0.27797E-03      0.00000E+00 *
    3 0.50000E+00 0.00000E+00 0.00000E+00      0.40473E-03      0.00000E+00 *
    4 0.75000E+00 0.00000E+00 0.00000E+00      0.29318E-03      0.00000E+00 *
    5 0.10000E+01 0.00000E+00 0.00000E+00      0.00000E+00 *    0.00000E+00 *
    6 0.00000E+00 0.25000E+00 0.00000E+00      0.00000E+00 *   -0.82463E-04
    7 0.25000E+00 0.25000E+00 0.00000E+00      0.28884E-03      0.98305E-05
    8 0.50000E+00 0.25000E+00 0.00000E+00      0.43063E-03      0.26788E-03
    9 0.75000E+00 0.25000E+00 0.00000E+00      0.31534E-03      0.57856E-03
   10 0.10000E+01 0.25000E+00 0.00000E+00      0.00000E+00 *    0.70326E-03
   11 0.00000E+00 0.50000E+00 0.00000E+00      0.00000E+00 *   -0.19400E-03
   12 0.25000E+00 0.50000E+00 0.00000E+00      0.28477E-03     -0.21048E-04
   13 0.50000E+00 0.50000E+00 0.00000E+00      0.45138E-03      0.50071E-03
   14 0.75000E+00 0.50000E+00 0.00000E+00      0.34652E-03      0.12130E-02
   15 0.10000E+01 0.50000E+00 0.00000E+00      0.00000E+00 *    0.14753E-02
   16 0.00000E+00 0.75000E+00 0.00000E+00      0.00000E+00 *   -0.28915E-03
   17 0.25000E+00 0.75000E+00 0.00000E+00      0.15318E-03     -0.80549E-04
   18 0.50000E+00 0.75000E+00 0.00000E+00      0.26465E-03      0.68598E-03
   19 0.75000E+00 0.75000E+00 0.00000E+00      0.96000E-04      0.19519E-02
   20 0.10000E+01 0.75000E+00 0.00000E+00      0.00000E+00 *    0.21745E-02
   21 0.00000E+00 0.10000E+01 0.00000E+00      0.00000E+00 *   -0.31289E-03
   22 0.25000E+00 0.10000E+01 0.00000E+00     -0.42129E-04     -0.80845E-04
   23 0.50000E+00 0.10000E+01 0.00000E+00      0.21493E-03      0.39107E-03
   24 0.75000E+00 0.10000E+01 0.00000E+00      0.00000E+00      0.00000E+00
```

```
 25 0.10000E+01 0.10000E+01 0.00000E+00      0.00000E+00 *   0.00000E+00

                S T R E S S E S   AND   S T R A I N S

ELEMENT NUMBER: 11

 G.P      SIG XX         SIG YY         TAU XY         SIG ZZ
VISCO-    EPS XX         EPS YY         GAM XY         EPS ZZ
PLASTIC   RATE XX        RATE YY        RATE XY        RATE ZZ      EFF.RATE

  1   -0.42871E-02  -0.55854E-02  0.89868E-03  -0.39490E-02
       0.00000E+00   0.00000E+00  0.00000E+00   0.00000E+00
       0.00000E+00   0.00000E+00  0.00000E+00   0.00000E+00   0.00000E+00
  2   -0.46028E-02  -0.57958E-02  0.13553E-02  -0.41594E-02
       0.00000E+00   0.00000E+00  0.00000E+00   0.00000E+00
       0.00000E+00   0.00000E+00  0.00000E+00   0.00000E+00   0.00000E+00
  3   -0.24606E-02  -0.28456E-02  0.84607E-03  -0.21225E-02
       0.00000E+00   0.00000E+00  0.00000E+00   0.00000E+00
       0.00000E+00   0.00000E+00  0.00000E+00   0.00000E+00   0.00000E+00
  4   -0.27767E-02  -0.30564E-02  0.13022E-02  -0.23332E-02
       0.17995E-06   0.34881E-07  0.13481E-05   0.40918E-06
       0.17279E-04   0.33633E-05  0.12959E-03   0.39345E-04   0.86011E-06

                S T R E S S E S   AND   S T R A I N S

ELEMENT NUMBER: 14

 G.P      SIG XX         SIG YY         TAU XY         SIG ZZ
VISCO-    EPS XX         EPS YY         GAM XY         EPS ZZ
PLASTIC   RATE XX        RATE YY        RATE XY        RATE ZZ      EFF.RATE

  1   -0.81963E-03  -0.22263E-02  0.76466E-03  -0.12184E-02
       0.10800E-04  -0.57899E-05  0.18046E-04   0.60692E-05
       0.10552E-02  -0.56712E-03  0.17637E-02   0.59530E-03   0.15271E-04
  2   -0.11198E-03  -0.17476E-02  0.52074E-03  -0.74385E-03
       0.20745E-04  -0.11684E-04  0.20695E-04   0.81894E-05
       0.20403E-02  -0.11510E-02  0.20320E-02   0.80746E-03   0.23778E-04
  3   -0.17804E-02  -0.36816E-02  0.88958E-03  -0.21848E-02
       0.27583E-05  -0.17394E-05  0.41992E-05   0.18036E-05
       0.28762E-03  -0.18111E-03  0.43865E-03   0.18792E-03   0.38904E-05
  4   -0.10697E-02  -0.32017E-02  0.64433E-03  -0.17085E-02
       0.10710E-04  -0.68485E-05  0.10593E-04   0.54577E-05
       0.10825E-02  -0.69153E-03  0.10723E-02   0.55094E-03   0.12845E-04

S O L U T I O N
***************

TIME STEP NUMBER         3
TOTAL TIME IS 0.25000E-01

              ENERGY     (ENERG)= 0.24594E-10

              SMALLEST PIVOT (ABSOLUTE VALUE)  = 0.37110E+00 EQUATION:    32
                           ALGEBRAIC VALUE = 0.37110E+00 EQUATION:    32
                           DETERMINANT= 0.12922E+07 * 10 **      0

 +++++ THERE IS AN INCREASE IN THE RESIDUAL ERROR, END OF TIME:     0.25000E-01
 NORM OF RESIDUAL SUM RATIO =  0.180347E-02

NODES     X             Y             Z          DISPLACEMENTS   (*   = IMPOSED)

    1 0.00000E+00 0.00000E+00 0.00000E+00      0.00000E+00 *    0.00000E+00 *
    2 0.25000E+00 0.00000E+00 0.00000E+00      0.27803E-03      0.00000E+00 *
    3 0.50000E+00 0.00000E+00 0.00000E+00      0.40478E-03      0.00000E+00 *
    4 0.75000E+00 0.00000E+00 0.00000E+00      0.29320E-03      0.00000E+00 *
    5 0.10000E+01 0.00000E+00 0.00000E+00      0.00000E+00 *    0.00000E+00 *
    6 0.00000E+00 0.25000E+00 0.00000E+00      0.00000E+00 *   -0.82568E-04
    7 0.25000E+00 0.25000E+00 0.00000E+00      0.28892E-03      0.97892E-05
    8 0.50000E+00 0.25000E+00 0.00000E+00      0.43070E-03      0.26794E-03
    9 0.75000E+00 0.25000E+00 0.00000E+00      0.31534E-03      0.57859E-03
   10 0.10000E+01 0.25000E+00 0.00000E+00      0.00000E+00 *    0.70326E-03
   11 0.00000E+00 0.50000E+00 0.00000E+00      0.00000E+00 *   -0.19432E-03
   12 0.25000E+00 0.50000E+00 0.00000E+00      0.28495E-03     -0.21132E-04
   13 0.50000E+00 0.50000E+00 0.00000E+00      0.45142E-03      0.50093E-03
   14 0.75000E+00 0.50000E+00 0.00000E+00      0.34653E-03      0.12130E-02
   15 0.10000E+01 0.50000E+00 0.00000E+00      0.00000E+00 *    0.14753E-02
   16 0.00000E+00 0.75000E+00 0.00000E+00      0.00000E+00 *   -0.28933E-03
   17 0.25000E+00 0.75000E+00 0.00000E+00      0.15276E-03     -0.80932E-04
   18 0.50000E+00 0.75000E+00 0.00000E+00      0.26514E-03      0.68628E-03
   19 0.75000E+00 0.75000E+00 0.00000E+00      0.96259E-04      0.19521E-02
   20 0.10000E+01 0.75000E+00 0.00000E+00      0.00000E+00 *    0.21746E-02
   21 0.00000E+00 0.10000E+01 0.00000E+00      0.00000E+00 *   -0.31293E-03
   22 0.25000E+00 0.10000E+01 0.00000E+00     -0.41043E-04     -0.82304E-04
   23 0.50000E+00 0.10000E+01 0.00000E+00      0.22150E-03      0.38940E-03
   24 0.75000E+00 0.10000E+01 0.00000E+00      0.00000E+00      0.00000E+00
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   25 0.10000E+01 0.10000E+01 0.00000E+00      0.00000E+00 *   0.00000E+00
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S T R E S S E S AND S T R A I N S

ELEMENT NUMBER: 11

G.P VISCO-PLASTIC	SIG XX / EPS XX / RATE XX	SIG YY / EPS YY / RATE YY	TAU XY / GAM XY / RATE XY	SIG ZZ / EPS ZZ / RATE ZZ	EFF.RATE
1	-0.42872E-02	-0.55850E-02	0.89900E-03	-0.39489E-02	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2	-0.46039E-02	-0.57961E-02	0.13557E-02	-0.41600E-02	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
3	-0.24606E-02	-0.28450E-02	0.84622E-03	-0.21222E-02	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
4	-0.27783E-02	-0.30570E-02	0.13017E-02	-0.23341E-02	
	0.43913E-06	0.85332E-07	0.32919E-05	0.99935E-06	
	0.16245E-04	0.31817E-05	0.12204E-03	0.37067E-04	0.21004E-05

S T R E S S E S AND S T R A I N S

ELEMENT NUMBER: 14

G.P VISCO-PLASTIC	SIG XX / EPS XX / RATE XX	SIG YY / EPS YY / RATE YY	TAU XY / GAM XY / RATE XY	SIG ZZ / EPS ZZ / RATE ZZ	EFF.RATE
1	-0.83212E-03	-0.22307E-02	0.75959E-03	-0.12251E-02	
	0.26628E-04	-0.14297E-04	0.44501E-04	0.14999E-04	
	0.10195E-02	-0.54998E-03	0.17048E-02	0.57844E-03	0.37670E-04
2	-0.12089E-03	-0.17393E-02	0.51354E-03	-0.74409E-03	
	0.51349E-04	-0.28949E-04	0.51175E-04	0.20301E-04	
	0.19912E-02	-0.11261E-02	0.19783E-02	0.79088E-03	0.58858E-04
3	-0.17801E-02	-0.36865E-02	0.89516E-03	-0.21866E-02	
	0.70726E-05	-0.44560E-05	0.10779E-04	0.46224E-05	
	0.30408E-03	-0.19108E-03	0.46501E-03	0.19848E-03	0.99779E-05
4	-0.10613E-02	-0.31922E-02	0.64583E-03	-0.17014E-02	
	0.26948E-04	-0.17221E-04	0.26677E-04	0.13722E-04	
	0.10985E-02	-0.70068E-03	0.10906E-02	0.55804E-03	0.32320E-04

S O L U T I O N
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TIME STEP NUMBER        43
TOTAL TIME IS 0.10000E+02

              ENERGY     (ENERG)= 0.66247E-13

              SMALLEST PIVOT (ABSOLUTE VALUE)  = 0.37017E+00 EQUATION:    32
                        ALGEBRAIC VALUE = 0.37017E+00 EQUATION:    32
                        DETERMINANT= 0.12226E+07 * 10 **      0


  ----- THERE IS A DECREASE IN THE RESIDUAL ERROR, END OF TIME:     0.10000E+02
  NORM OF RESIDUAL SUM RATIO =  0.976842E-04
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NODES	X	Y	Z	DISPLACEMENTS	(* = IMPOSED)
1	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00 *	0.00000E+00 *
2	0.25000E+00	0.00000E+00	0.00000E+00	0.28337E-03	0.00000E+00 *
3	0.50000E+00	0.00000E+00	0.00000E+00	0.40913E-03	0.00000E+00 *
4	0.75000E+00	0.00000E+00	0.00000E+00	0.29460E-03	0.00000E+00 *
5	0.10000E+01	0.00000E+00	0.00000E+00	0.00000E+00 *	0.00000E+00 *
6	0.00000E+00	0.25000E+00	0.00000E+00	0.00000E+00 *	-0.92122E-04
7	0.25000E+00	0.25000E+00	0.00000E+00	0.29589E-03	0.63953E-05
8	0.50000E+00	0.25000E+00	0.00000E+00	0.43666E-03	0.27381E-03
9	0.75000E+00	0.25000E+00	0.00000E+00	0.31559E-03	0.58118E-03
10	0.10000E+01	0.25000E+00	0.00000E+00	0.00000E+00 *	0.70268E-03
11	0.00000E+00	0.50000E+00	0.00000E+00	0.00000E+00 *	-0.22418E-03
12	0.25000E+00	0.50000E+00	0.00000E+00	0.30101E-03	-0.27785E-04
13	0.50000E+00	0.50000E+00	0.00000E+00	0.45592E-03	0.52018E-03
14	0.75000E+00	0.50000E+00	0.00000E+00	0.34886E-03	0.12157E-02
15	0.10000E+01	0.50000E+00	0.00000E+00	0.00000E+00 *	0.14747E-02
16	0.00000E+00	0.75000E+00	0.00000E+00	0.00000E+00 *	-0.31539E-03
17	0.25000E+00	0.75000E+00	0.00000E+00	0.12350E-03	-0.10982E-03
18	0.50000E+00	0.75000E+00	0.00000E+00	0.30469E-03	0.71614E-03
19	0.75000E+00	0.75000E+00	0.00000E+00	0.11404E-03	0.19618E-02
20	0.10000E+01	0.75000E+00	0.00000E+00	0.00000E+00 *	0.21796E-02
21	0.00000E+00	0.10000E+01	0.00000E+00	0.00000E+00 *	-0.31683E-03
22	0.25000E+00	0.10000E+01	0.00000E+00	0.82916E-04	-0.27543E-03
23	0.50000E+00	0.10000E+01	0.00000E+00	0.11347E-02	0.15824E-03
24	0.75000E+00	0.10000E+01	0.00000E+00	0.00000E+00	0.00000E+00
25	0.10000E+01	0.10000E+01	0.00000E+00	0.00000E+00 *	0.00000E+00

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                S T R E S S E S   AND   S T R A I N S

ELEMENT NUMBER: 14

 G.P      SIG XX         SIG YY         TAU XY         SIG ZZ
VISCO-    EPS XX         EPS YY         GAM XY         EPS ZZ
PLASTIC   RATE XX        RATE YY        RATE XY        RATE ZZ      EFF.RATE

   1   -0.13390E-02   -0.27014E-02   0.64038E-03   -0.16161E-02
        0.11008E-02   -0.65280E-03   0.17933E-02    0.69678E-03
        0.24052E-05   -0.15292E-05   0.36985E-05    0.16048E-05    0.15779E-02
   2    0.49938E-04   -0.27863E-03   0.57362E-04   -0.91479E-04
        0.35954E-02   -0.21251E-02   0.27610E-02    0.13883E-02
        0.21813E-04   -0.12558E-04   0.12001E-04    0.70198E-05    0.39402E-02
   3   -0.26739E-02   -0.46140E-02   0.12519E-02   -0.29152E-02
        0.10839E-02   -0.65645E-03   0.19582E-02    0.77681E-03
        0.60362E-06   -0.36097E-06   0.12448E-05    0.48367E-06    0.16599E-02
   4   -0.82303E-03   -0.19012E-02   0.40950E-03   -0.10897E-02
        0.33935E-02   -0.21390E-02   0.38900E-02    0.18241E-02
        0.22503E-04   -0.14549E-04   0.28146E-04    0.13339E-04    0.42434E-02
time and step:    10.0475619025081  44

***STEP 2 (t=10): excavate element 11,12****

***THESE ELEMENTS ARE CHANGED TO MATERIAL GROUP  2
   11   12

***THESE NODES HAVE BEEN ADDED OR DELETED:
   19   20

 S O L U T I O N
 ***************

 TIME STEP NUMBER        44
 TOTAL TIME IS 0.10048E+02

              ENERGY     (ENERG)= 0.49501E-05

              SMALLEST PIVOT (ABSOLUTE VALUE)  = 0.30114E+00 EQUATION:   32
                          ALGEBRAIC VALUE = 0.30114E+00 EQUATION:   32
                          DETERMINANT= 0.31213E+05 * 10 **     0

   +++++ THERE IS AN INCREASE IN THE RESIDUAL ERROR, END OF TIME:    0.10048E+02
   NORM OF RESIDUAL SUM RATIO =  0.885923E+00


 NODES     X            Y            Z          DISPLACEMENTS   (*   = IMPOSED)

     1 0.00000E+00 0.00000E+00 0.00000E+00      0.00000E+00 *   0.00000E+00 *
     2 0.25000E+00 0.00000E+00 0.00000E+00      0.68288E-03     0.00000E+00 *
     3 0.50000E+00 0.00000E+00 0.00000E+00      0.10153E-02     0.00000E+00 *
     4 0.75000E+00 0.00000E+00 0.00000E+00      0.73632E-03     0.00000E+00 *
     5 0.10000E+01 0.00000E+00 0.00000E+00      0.00000E+00 *   0.00000E+00 *
     6 0.00000E+00 0.25000E+00 0.00000E+00      0.00000E+00 *  -0.26928E-03
     7 0.25000E+00 0.25000E+00 0.00000E+00      0.67949E-03    -0.54930E-04
     8 0.50000E+00 0.25000E+00 0.00000E+00      0.10114E-02     0.57189E-03
     9 0.75000E+00 0.25000E+00 0.00000E+00      0.74941E-03     0.13991E-02
    10 0.10000E+01 0.25000E+00 0.00000E+00      0.00000E+00 *   0.16871E-02
    11 0.00000E+00 0.50000E+00 0.00000E+00      0.00000E+00 *  -0.54474E-03
    12 0.25000E+00 0.50000E+00 0.00000E+00      0.57995E-03    -0.17361E-03
    13 0.50000E+00 0.50000E+00 0.00000E+00      0.89127E-03     0.11296E-02
    14 0.75000E+00 0.50000E+00 0.00000E+00      0.42589E-03     0.29570E-02
    15 0.10000E+01 0.50000E+00 0.00000E+00      0.00000E+00 *   0.32187E-02
    16 0.00000E+00 0.75000E+00 0.00000E+00      0.00000E+00 *  -0.80683E-03
    17 0.25000E+00 0.75000E+00 0.00000E+00      0.40322E-03    -0.33539E-03
    18 0.50000E+00 0.75000E+00 0.00000E+00      0.96282E-03     0.10625E-02
    19 0.75000E+00 0.75000E+00 0.00000E+00      0.00000E+00     0.00000E+00
    20 0.10000E+01 0.75000E+00 0.00000E+00      0.00000E+00 *   0.00000E+00
    21 0.00000E+00 0.10000E+01 0.00000E+00      0.00000E+00 *  -0.83011E-03
    22 0.25000E+00 0.10000E+01 0.00000E+00     -0.22139E-04    -0.63125E-03
    23 0.50000E+00 0.10000E+01 0.00000E+00      0.68711E-03     0.93798E-03
    24 0.75000E+00 0.10000E+01 0.00000E+00      0.00000E+00     0.00000E+00
    25 0.10000E+01 0.10000E+01 0.00000E+00      0.00000E+00 *   0.00000E+00

                S T R E S S E S   AND   S T R A I N S

ELEMENT NUMBER:  5

 G.P      SIG XX         SIG YY         TAU XY         SIG ZZ
VISCO-    EPS XX         EPS YY         GAM XY         EPS ZZ
PLASTIC   RATE XX        RATE YY        RATE XY        RATE ZZ      EFF.RATE
```

1	-0.40741E-02	-0.10814E-01	0.32350E-03	-0.59554E-02	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	
	0.12507E-02	-0.90429E-03	0.20685E-03	0.64921E-03	0.00000E+00
2	-0.45667E-02	-0.11143E-01	0.45280E-03	-0.62838E-02	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	
	0.22681E-03	-0.16705E-03	0.54239E-04	0.12397E-03	0.00000E+00
3	-0.35569E-02	-0.10039E-01	0.24139E-03	-0.54382E-02	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	
	0.18134E-02	-0.12951E-02	0.23154E-03	0.91116E-03	0.00000E+00
4	-0.40495E-02	-0.10367E-01	0.37070E-03	-0.57666E-02	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	
	0.75446E-03	-0.54954E-03	0.15303E-03	0.40003E-03	0.00000E+00

S T R E S S E S AND S T R A I N S

ELEMENT NUMBER: 6

G.P VISCO-PLASTIC	SIG XX EPS XX RATE XX	SIG YY EPS YY RATE YY	TAU XY GAM XY RATE XY	SIG ZZ EPS ZZ RATE ZZ	EFF.RATE
1	-0.53871E-02	-0.10420E-01	0.95124E-03	-0.63229E-02	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2	-0.54889E-02	-0.10488E-01	0.15091E-02	-0.63909E-02	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
3	-0.31555E-02	-0.70720E-02	0.93427E-03	-0.40914E-02	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
4	-0.32574E-02	-0.71408E-02	0.14922E-02	-0.41593E-02	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	
	0.89553E-03	-0.58791E-03	0.11400E-02	0.55101E-03	0.00000E+00

S T R E S S E S AND S T R A I N S

ELEMENT NUMBER: 7

G.P VISCO-PLASTIC	SIG XX EPS XX RATE XX	SIG YY EPS YY RATE YY	TAU XY GAM XY RATE XY	SIG ZZ EPS ZZ RATE ZZ	EFF.RATE
1	-0.65526E-02	-0.76505E-02	0.12507E-02	-0.56812E-02	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2	-0.75591E-02	-0.83215E-02	0.20756E-02	-0.63522E-02	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
3	-0.32528E-02	-0.27009E-02	0.10829E-02	-0.23815E-02	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
4	-0.42594E-02	-0.33719E-02	0.19079E-02	-0.30525E-02	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	
	-0.61468E-04	0.47605E-03	0.23111E-02	0.66949E-03	0.00000E+00

S T R E S S E S AND S T R A I N S

ELEMENT NUMBER: 9

G.P VISCO-PLASTIC	SIG XX EPS XX RATE XX	SIG YY EPS YY RATE YY	TAU XY GAM XY RATE XY	SIG ZZ EPS ZZ RATE ZZ	EFF.RATE
1	-0.17256E-02	-0.64642E-02	0.50711E-03	-0.32759E-02	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	
	0.30072E-02	-0.20283E-02	0.10778E-02	0.13598E-02	0.00000E+00
2	-0.26003E-02	-0.70473E-02	0.58985E-03	-0.38590E-02	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	
	0.10677E-02	-0.75475E-03	0.48344E-03	0.55181E-03	0.00000E+00
3	-0.13947E-02	-0.59678E-02	0.36134E-03	-0.29450E-02	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	
	0.33260E-02	-0.22240E-02	0.87707E-03	0.14445E-02	0.00000E+00
4	-0.22693E-02	-0.65508E-02	0.44408E-03	-0.35281E-02	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	
	0.13152E-02	-0.92479E-03	0.46466E-03	0.65663E-03	0.00000E+00

S T R E S S E S AND S T R A I N S

ELEMENT NUMBER: 10

G.P VISCO-PLASTIC	SIG XX EPS XX RATE XX	SIG YY EPS YY RATE YY	TAU XY GAM XY RATE XY	SIG ZZ EPS ZZ RATE ZZ	EFF.RATE
1	-0.26919E-02	-0.66363E-02	0.17128E-02	-0.37313E-02	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	
	0.22696E-02	-0.13787E-02	0.31684E-02	0.13082E-02	0.00000E+00
2	-0.14632E-02	-0.58172E-02	0.17909E-02	-0.29122E-02	

	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	
	0.48336E-02	-0.27332E-02	0.62249E-02	0.23155E-02	0.00000E+00
3	-0.23795E-02	-0.61678E-02	0.19176E-02	-0.34189E-02	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	
	0.30321E-02	-0.17075E-02	0.47983E-02	0.17317E-02	0.00000E+00
4	-0.11508E-02	-0.53486E-02	0.19957E-02	-0.25998E-02	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	
	0.55592E-02	-0.29264E-02	0.80684E-02	0.26302E-02	0.00000E+00

S T R E S S E S AND S T R A I N S

ELEMENT NUMBER: 13

G.P VISCO-PLASTIC	SIG XX EPS XX RATE XX	SIG YY EPS YY RATE YY	TAU XY GAM XY RATE XY	SIG ZZ EPS ZZ RATE ZZ	EFF.RATE
1	0.55649E-03	-0.14031E-02	0.46274E-03	-0.33863E-03	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	
	0.37692E-02	-0.20288E-02	0.27384E-02	0.11207E-02	0.00000E+00
2	-0.15493E-02	-0.28069E-02	0.23792E-03	-0.17425E-02	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
3	-0.34278E-03	-0.27520E-02	0.11177E-03	-0.12379E-02	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	
	0.22333E-02	-0.14398E-02	0.34081E-03	0.86859E-03	0.00000E+00
4	-0.24486E-02	-0.41558E-02	-0.11305E-03	-0.26418E-02	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00

S T R E S S E S AND S T R A I N S

ELEMENT NUMBER: 14

G.P VISCO-PLASTIC	SIG XX EPS XX RATE XX	SIG YY EPS YY RATE YY	TAU XY GAM XY RATE XY	SIG ZZ EPS ZZ RATE ZZ	EFF.RATE
1	0.47448E-03	-0.15083E-02	0.83311E-03	-0.41354E-03	
	0.11009E-02	-0.65288E-03	0.17935E-02	0.69686E-03	
	0.40529E-02	-0.19345E-02	0.50314E-02	0.13714E-02	0.15781E-02
2	-0.15878E-02	-0.14499E-02	0.74856E-03	-0.12151E-02	
	0.35964E-02	-0.21257E-02	0.27615E-02	0.13886E-02	
	0.54900E-05	0.18290E-04	0.13893E-03	0.40079E-04	0.39412E-02
3	0.10411E-02	-0.63068E-03	0.86649E-03	0.16418E-03	
	0.10840E-02	-0.65646E-03	0.19582E-02	0.77684E-03	
	0.47778E-02	-0.18375E-02	0.68573E-02	0.13077E-02	0.16600E-02
4	-0.62122E-03	-0.29328E-03	0.51266E-03	-0.36580E-03	
	0.33946E-02	-0.21396E-02	0.38914E-02	0.18247E-02	
	-0.58099E-04	0.50665E-03	0.17657E-02	0.38177E-03	0.42448E-02

S O L U T I O N
****

TIME STEP NUMBER 181
TOTAL TIME IS 0.47175E+03

ENERGY (ENERG)= 0.22043E-10

SMALLEST PIVOT (ABSOLUTE VALUE) = 0.84919E-01 EQUATION: 31
ALGEBRAIC VALUE = 0.84919E-01 EQUATION: 31
DETERMINANT= 0.19240E+03 * 10 ** 0

+++++ THERE IS AN INCREASE IN THE RESIDUAL ERROR, END OF TIME: 0.47175E+03
NORM OF RESIDUAL SUM RATIO = 0.592000E-02

NODES	X	Y	Z	DISPLACEMENTS	(* = IMPOSED)
1	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00 *	0.00000E+00 *
2	0.25000E+00	0.00000E+00	0.00000E+00	0.76243E-03	0.00000E+00 *
3	0.50000E+00	0.00000E+00	0.00000E+00	0.11077E-02	0.00000E+00 *
4	0.75000E+00	0.00000E+00	0.00000E+00	0.76573E-03	0.00000E+00 *
5	0.10000E+01	0.00000E+00	0.00000E+00	0.00000E+00 *	0.00000E+00 *
6	0.00000E+00	0.25000E+00	0.00000E+00	0.00000E+00 *	-0.29917E-03
7	0.25000E+00	0.25000E+00	0.00000E+00	0.88035E-03	-0.16903E-03
8	0.50000E+00	0.25000E+00	0.00000E+00	0.12279E-02	0.68411E-03
9	0.75000E+00	0.25000E+00	0.00000E+00	0.85955E-03	0.14110E-02
10	0.10000E+01	0.25000E+00	0.00000E+00	0.00000E+00 *	0.16890E-02
11	0.00000E+00	0.50000E+00	0.00000E+00	0.00000E+00 *	-0.68566E-03
12	0.25000E+00	0.50000E+00	0.00000E+00	0.11528E-02	-0.77558E-03
13	0.50000E+00	0.50000E+00	0.00000E+00	0.18326E-02	0.15284E-02
14	0.75000E+00	0.50000E+00	0.00000E+00	0.83007E-03	0.31641E-02
15	0.10000E+01	0.50000E+00	0.00000E+00	0.00000E+00 *	0.33559E-02
16	0.00000E+00	0.75000E+00	0.00000E+00	0.00000E+00 *	-0.24195E-02

17	0.25000E+00	0.75000E+00	0.00000E+00	0.54771E-02	-0.36566E-02
18	0.50000E+00	0.75000E+00	0.00000E+00	0.15393E-01	0.20345E-02
19	0.75000E+00	0.75000E+00	0.00000E+00	0.00000E+00	0.00000E+00
20	0.10000E+01	0.75000E+00	0.00000E+00	0.00000E+00 *	0.00000E+00
21	0.00000E+00	0.10000E+01	0.00000E+00	0.00000E+00 *	-0.65793E-02
22	0.25000E+00	0.10000E+01	0.00000E+00	0.91825E-02	-0.93224E-02
23	0.50000E+00	0.10000E+01	0.00000E+00	0.17907E-01	-0.73130E-03
24	0.75000E+00	0.10000E+01	0.00000E+00	0.00000E+00	0.00000E+00
25	0.10000E+01	0.10000E+01	0.00000E+00	0.00000E+00 *	0.00000E+00

S T R E S S E S AND S T R A I N S

ELEMENT NUMBER: 7

G.P VISCO-PLASTIC	SIG XX / EPS XX / RATE XX	SIG YY / EPS YY / RATE YY	TAU XY / GAM XY / RATE XY	SIG ZZ / EPS ZZ / RATE ZZ	EFF.RATE
1	-0.67173E-02	-0.64877E-02	0.19853E-02	-0.52820E-02	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2	-0.98560E-02	-0.85801E-02	0.27348E-02	-0.73744E-02	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
3	-0.38217E-02	-0.24000E-02	0.11721E-02	-0.24887E-02	
	-0.26104E-03	0.50734E-03	0.13732E-02	0.47907E-03	
	-0.52990E-06	0.98548E-06	0.24986E-05	0.89096E-06	0.99982E-03
4	-0.70191E-02	-0.44891E-02	0.18724E-02	-0.46033E-02	
	-0.30827E-04	0.14140E-03	0.64484E-03	0.19569E-03	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.42215E-03

S T R E S S E S AND S T R A I N S

ELEMENT NUMBER: 9

G.P VISCO-PLASTIC	SIG XX / EPS XX / RATE XX	SIG YY / EPS YY / RATE YY	TAU XY / GAM XY / RATE XY	SIG ZZ / EPS ZZ / RATE ZZ	EFF.RATE
1	-0.49082E-02	-0.11831E-01	0.29991E-03	-0.66955E-02	
	0.95306E-02	-0.69880E-02	0.19971E-02	0.51481E-02	
	0.76123E-05	-0.56449E-05	0.11487E-05	0.41893E-05	0.10601E-01
2	0.24444E-03	0.19186E-03	-0.79467E-05	0.17452E-03	
	0.25094E-01	-0.13236E-01	-0.22039E-02	0.69313E-02	
	0.31609E-04	-0.41103E-06	-0.96774E-05	-0.10967E-04	0.25899E-01
3	-0.85728E-02	-0.17404E-01	0.29655E-02	-0.10391E-01	
	0.44889E-02	-0.31705E-02	0.33906E-02	0.25978E-02	
	0.97614E-06	-0.68421E-06	0.71151E-05	0.63437E-06	0.53979E-02
4	-0.11277E-02	-0.28588E-02	0.32297E-03	-0.15946E-02	
	0.23406E-01	-0.16633E-01	0.12450E-01	0.12516E-01	
	0.14005E-05	-0.98671E-06	0.89079E-06	0.75668E-06	0.26587E-01

S T R E S S E S AND S T R A I N S

ELEMENT NUMBER: 10

G.P VISCO-PLASTIC	SIG XX / EPS XX / RATE XX	SIG YY / EPS YY / RATE YY	TAU XY / GAM XY / RATE XY	SIG ZZ / EPS ZZ / RATE ZZ	EFF.RATE
1	-0.91230E-02	-0.13176E-01	0.41093E-02	-0.89195E-02	
	0.11360E-01	-0.63325E-02	0.27493E-01	0.10164E-01	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.20940E-01
2	0.24060E-03	0.22394E-03	0.12021E-04	0.18581E-03	
	0.44321E-01	-0.11399E-01	0.61306E-01	0.68456E-02	
	0.20711E-04	0.10220E-04	0.15138E-04	-0.13783E-04	0.54814E-01
3	-0.49073E-02	-0.53234E-02	0.21606E-02	-0.40923E-02	
	0.13086E-01	-0.25128E-02	0.63755E-01	0.20026E-01	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.42178E-01
4	0.21365E-03	0.17651E-03	0.38358E-04	0.15606E-03	
	0.37237E-01	-0.40692E-02	0.74497E-01	0.67115E-02	
	0.26796E-04	0.51154E-05	0.44789E-04	-0.68228E-05	0.54968E-01

S T R E S S E S AND S T R A I N S

ELEMENT NUMBER: 14

G.P VISCO-PLASTIC	SIG XX / EPS XX / RATE XX	SIG YY / EPS YY / RATE YY	TAU XY / GAM XY / RATE XY	SIG ZZ / EPS ZZ / RATE ZZ	EFF.RATE
1	0.16051E-03	0.59277E-04	0.48406E-04	0.87915E-04	
	0.55379E-01	-0.27806E-01	0.58377E-01	0.18154E-01	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.63029E-01
2	-0.38403E-03	-0.10598E-02	0.23474E-03	-0.57751E-03	
	0.39003E-01	-0.23397E-01	0.49817E-01	0.20907E-01	
	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.50327E-01
3	0.14797E-03	0.48917E-04	0.62953E-04	0.78756E-04	

```
      0.41875E-01  -0.15512E-01   0.38575E-01   0.51967E-02
      0.00000E+00   0.00000E+00   0.00000E+00   0.00000E+00   0.43501E-01
 4    0.77065E-04  -0.13091E-0.   0.85489E-04  -0.21538E-04
      0.36934E-01  -0.15178E-01   0.44383E-01   0.91065E-02
      0.42416E-05  -0.19616E-05   0.50997E-05   0.13006E-05   0.42540E-01

S O L U T I O N
***************

TIME STEP NUMBER       182
TOTAL TIME IS 0.50088E+03


CURRENT TIME EXCEEDS FINAL TIME OF ANALYSIS (T= 0.50000E+03)
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RUN TERMINATED
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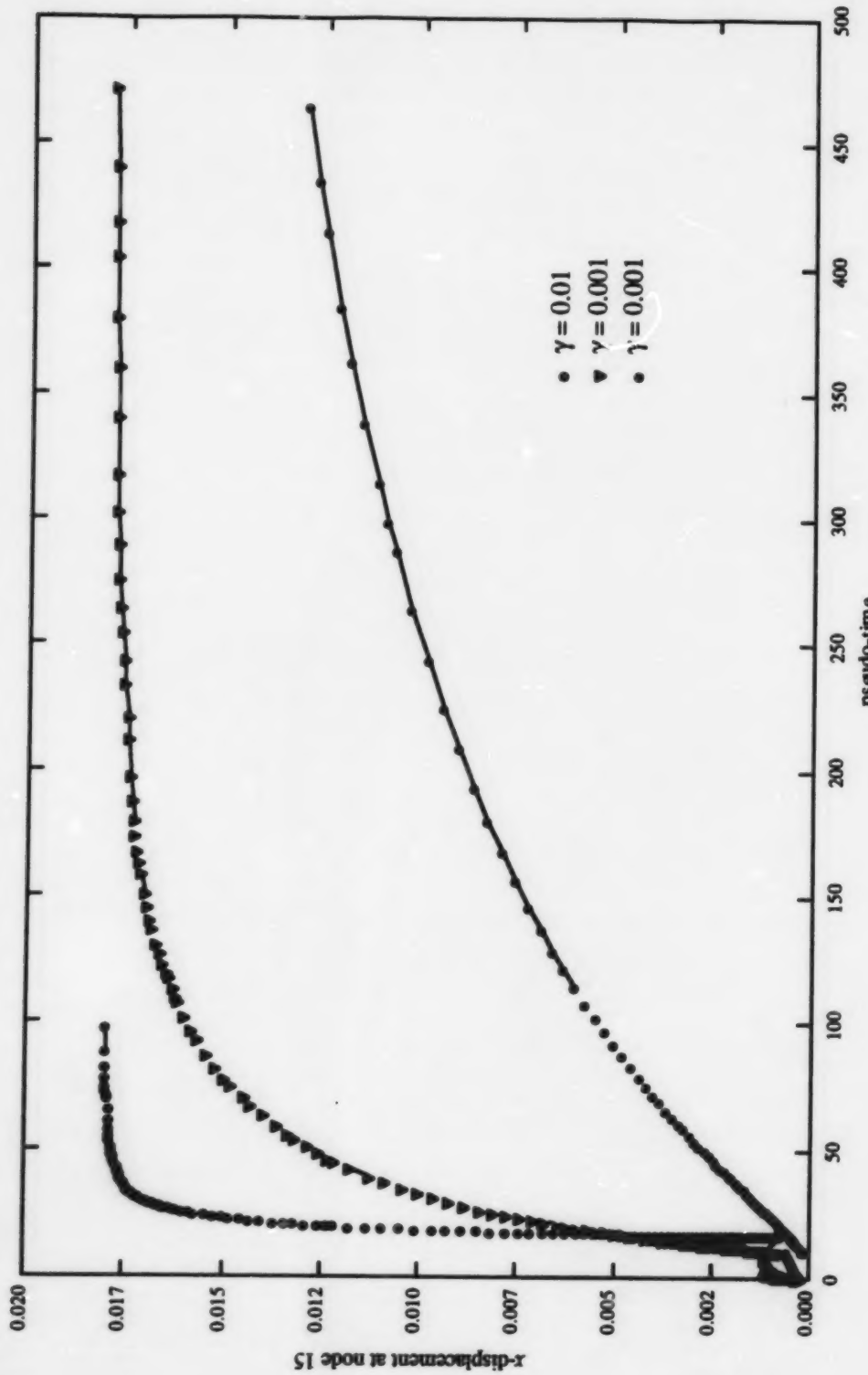

Evolution of x-displacement at node 15 for different fluidity values